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IDENTIFIERS Lubrication Systems

ABSTRACT

This text is intended to provide students with basic information on conducting preventive maintenance on agricultural machinery. The following topics are covered in the individual chapters: the importance of preventive maintenance and recommended service intervals; engine intake and exhaust systems (air cleaners, turbochargers, intake and exhaust valves, exhaust manifolds and mufflers, crankcase ventilation, and testing procedures); engine fuel systems (fuel selection, procedures for refueling machines, fuel systems, and engine governors); lubricating systems (operating and servicing lubrication systems and selecting engine oils); engine cooling systems; engine electrical systems; power trains; hydraulic systems; other components (operator's cabs, manual steering, steering axles and wheels, manual brakes, tires, grease fittings, belt and chain drives, gear drives, and lighting and accessories); tune-up and storage (engine tune-up, visual inspection, dynamometer tests, engine tune-up charts, and machine storage); and troubleshooting procedures. Concluding each chapter are a chapter summary and a set of self-test questions. Answers to the questions are also provided. (MN)

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Preventive Maintenance



**FUNDAMENTALS OF
MACHINE OPERATION**



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PUBLISHER

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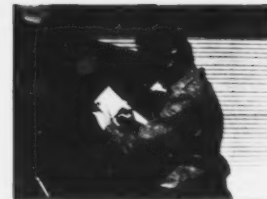
We have a
long-range interest in
good machine operation

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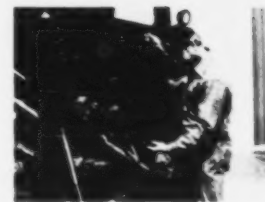
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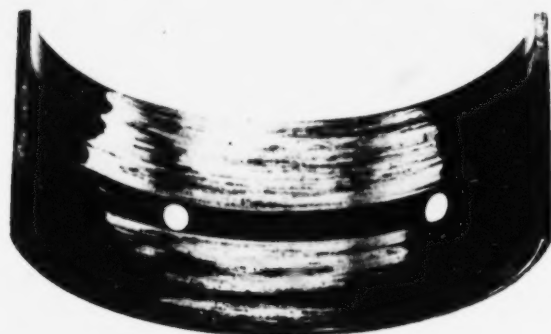
Fig. 1—Preventive Maintenance Keeps Machines Going When Jobs Are The Toughest

IMPORTANCE OF PREVENTIVE MAINTENANCE

Do you know the leading cause of premature failure in agricultural machines today? *Putting things off until tomorrow!* Yes, how many times have you heard, "I'll grease it tomorrow." Tomorrow comes and work is waiting—no time to grease it now.

Putting it off becomes a bad habit which leads to machine breakdown or high operating costs. You can make preventive maintenance a good habit. Just do

Fig. 2—Damaged Bearing Caused By Lack Of Lubrication



one thing: *Always perform maintenance either at the end of the day or early in the morning before you go to the field.*

By knowing the fundamentals of good preventive maintenance, you can perform it efficiently and correctly. Then you will be assured of getting the most out of your equipment. And you will be pleased with your efforts and savings.

Preventive maintenance can do three things:

- Reduce failures
- Save on operating costs
- Keep equipment safe

Let's look at each of these.

REDUCE FAILURES

When the work load is heaviest, your equipment needs preventive maintenance the most. You can't afford to have your machine down when the crop has to be planted in the spring or harvested in the fall. You won't, of course, prevent the possibility of failure, but you will reduce it to a minimum.

SAVE ON OPERATING COSTS

Believe it or not, the few dollars it costs to perform preventive maintenance will pay for themselves many times over. For example, an engine tune-up can save you a possible 15 percent in fuel consumption and increase maximum power by more than 10 percent. On

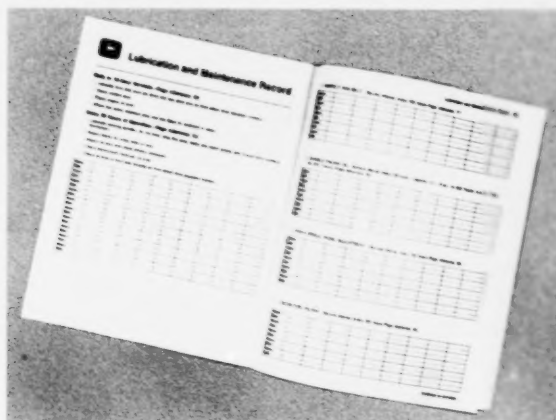


Fig. 3—Preventive Maintenance Schedule

a 100-horsepower (75 kW) tractor, this could mean 4 or 5 gallons (15 to 19 liters) of fuel saved each day, plus a bonus of 10 extra horsepower (7.5 kW) to work with. These savings can be measured in dollars and cents. And maintenance of other components will save you even more in repairs during the life of your equipment. All these things mean more profit for you.

Preventive maintenance also provides a cumulative effect in terms of energy conservation. A properly maintained engine burns less fuel per hour; a well-cared-for machine can do more work per hour; so, fewer operating hours are required to complete needed tasks. These reductions in fuel consumption save dollars, and conserve energy.

Fig. 4—Use Records Instead Of Your Memory—It Will Pay

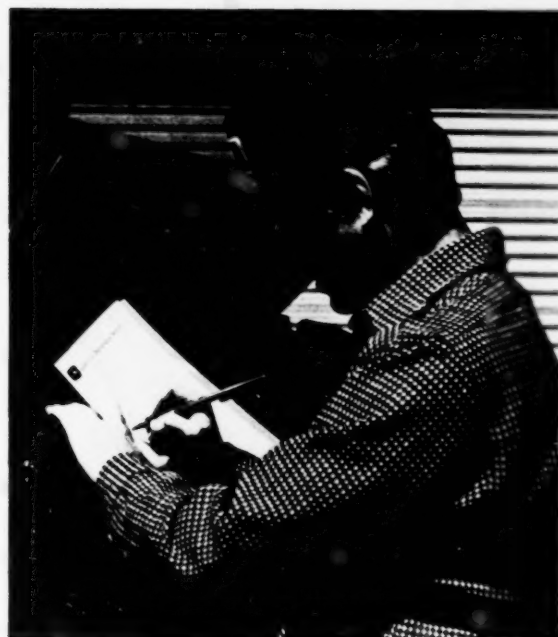


Fig. 5—Recording Hour Meter Readings Tells When Periodic Services Are Needed

KEEP EQUIPMENT SAFE TO OPERATE

If your machine is not performing well, you tend to take chances to save the time lost by poor performance. Of if you have a problem while working, you may try to fix it without stopping or turning off the machine. Maybe you haven't checked the brakes lately and you suddenly find yourself careening out of control. To keep your machine as safe as possible, it must be in excellent condition. Good preventive maintenance will assure you of a safe machine to operate.

KEEPING RECORDS

A good way to be sure that all maintenance is performed on schedule is to keep records. A simple form like the one shown in Fig. 3 is easy to use. You can make up your own form or you may find one available from your local implement or petroleum supply dealer. Such forms are also provided in some operator's manuals.

Follow the recommendations in your operator's manual for specific service intervals. Enter the various jobs to be performed under the "hours of operation" headings. Then check off the intervals of service after they are performed. It only takes a few minutes each day.

Keep this record in a handy place, such as near the service center of the farm.

Many machines have an hour meter which operates whenever the engine is running and shows the total hours of operation. Record the hour meter reading and watch this meter to tell when services are required.

RECOMMENDED SERVICE INTERVALS

The American Society of Agricultural Engineers (ASAE) recommend service on machines at regular hourly intervals. These periods are commonly after 5, 10, 50, 100, 250, 500 and 1000 hours of operation. See the chart in Fig. 6 for typical service on a tractor.

The hourly intervals represent days of operation as shown below:

- 5 Hours (Twice Daily)
- 10 Hours (Daily)
- 50 Hours (Weekly)
- 250 Hours (Monthly)
- 500 Hours (Bimonthly)
- 1000 Hours (Seasonally)

However, most farm machines are only operated 250 to 500 hours a year, so the yearly or twice-yearly services can often be combined with the other intervals and completed at the same time.

Keep in mind that the suggested intervals of service shown in this book are the *average* intervals between different machines and manufacturers. Since recommended intervals of service vary widely between machines, refer to your operator's manual for specific instructions. Here we are primarily concerned with the fundamentals of preventive maintenance and this

book is not intended as a maintenance manual for specific machines.

The intervals of service are cumulative. For example: you should perform 10-hour maintenance every ten

Fig. 7—Improper Operation Causes Premature Wear (Spinning Wear On Tire)

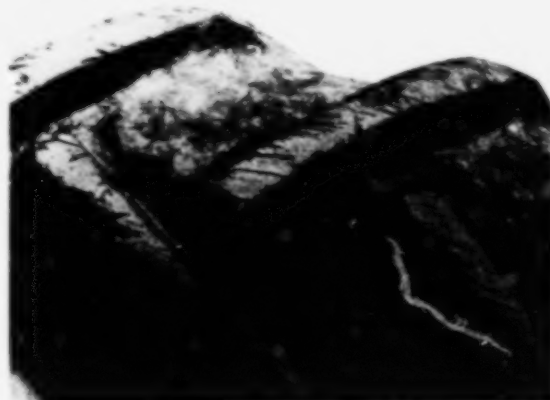


Fig. 6—Typical ASAE Service Intervals For A Tractor

LUBRICATION INTERVAL	SYMBOL*
5 HOURS	△
10 HOURS	○
50 HOURS	□
100 HOURS	◇
250 HOURS	▽
500 HOURS	◇
1000 HOURS	○
2500 HOURS	△

*OPTIONAL

LUBRICATION CHART

TRACTOR, WHEEL TYPE			
INTERVAL HOURS	POINT	IDENTIFICATION	LUBRICANT
5	1-ORANGE	AIR CLEANER	E.O.
10	2-RED	STEERING MECHANISM, LIFT MECHANISM	M.P.G.
50	3-YELLOW	CLUTCH THROW-OUT BEARING	M.P.G.
100	4-GREEN	ENGINE OIL CHANGE	E.O.
250	5-BLUE	STEERING GEAR HOUSING, CHECK GENERATOR BEARINGS, DISTRIBUTOR	E.O.
500	6-WHITE	REPACK FRONT WHEEL BEARINGS	M.P.G.
1000	7-BROWN	TRANSMISSION OIL CHANGE, TORQUE TUBE OIL CHANGE, POWER STEERING RESERVOIR	M.P.L. E.O. SPEC. O

LUBRICANT ABBREVIATIONS

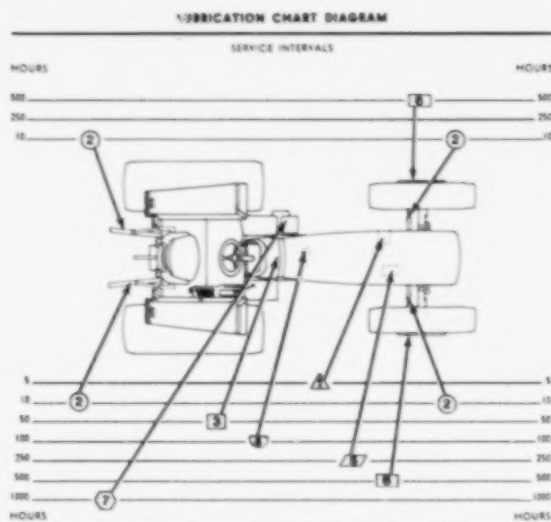
E.O. ENGINE OIL

M.P.G. MULTIPURPOSE TYPE GREASE

M.P.L. MULTIPURPOSE TYPE GEAR LUBRICANT

SPEC. O AUTOMATIC TRANSMISSION FLUID—TYPE A

LUBRICATION INTERVAL CHART AND DIAGRAM FOR TRACTORS AND FARM MACHINERY



hours, including at the 50-, 100-, 250-, 500-, and 1000-hour intervals.

PROPER OPERATION TO PREVENT ABUSE

Agricultural machines are designed for special kinds of work. They are built tough, but are not "hot rods" and they must be handled with respect. Improper operation causes premature wear and damage. Look at the tire in Fig. 7. It has been in operation only a few hours. During that time, the operator caused the tire to spin, which resulted in severe, premature wear. Inadequate inflation can cause equally serious tire damage.

Read the following chart for do's and don'ts of operation.

TIPS FOR GOOD MACHINE OPERATION

DO:

1. Follow suggestions in your operator's manual.
2. Perform daily (5 and 10 hour) maintenance before using machine.
3. Check the machine for damage and potential failures before starting it.
4. Run the engine until it is warm before putting it under load.
5. Let a hot engine run a few minutes without load so that it cools before shutting it off.
6. Keep bolts and nuts tight.
7. Watch the instrument panel.
8. Keep the machine properly serviced.
9. See a serviceman for major repairs.
10. Operate at safe speeds.

Fig. 8—Study Your Operator's Manual

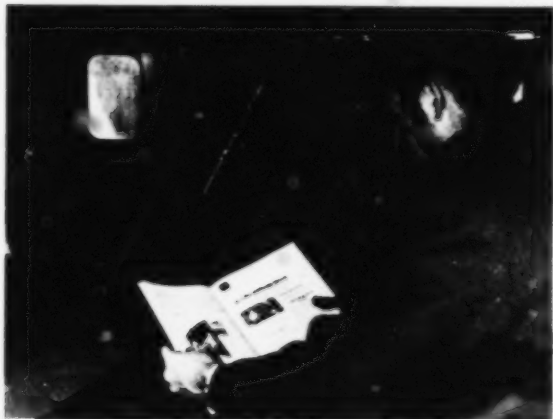


Fig. 9—Turn Off Engine Before Servicing Machine

DON'T:

1. Jump on the machine, start it, and take off with a cold engine.
2. Start the engine and turn it off before it has warmed up.
3. Jam the transmission into gear.
4. Snap or pop the clutch.
5. Spin the tires.
6. Overload the capacity of the machine.
7. Let the engine idle for long periods of time.
8. Store a machine without properly preparing it for storage.
9. Neglect to perform periodic maintenance on schedule.
10. Remove safety shields.

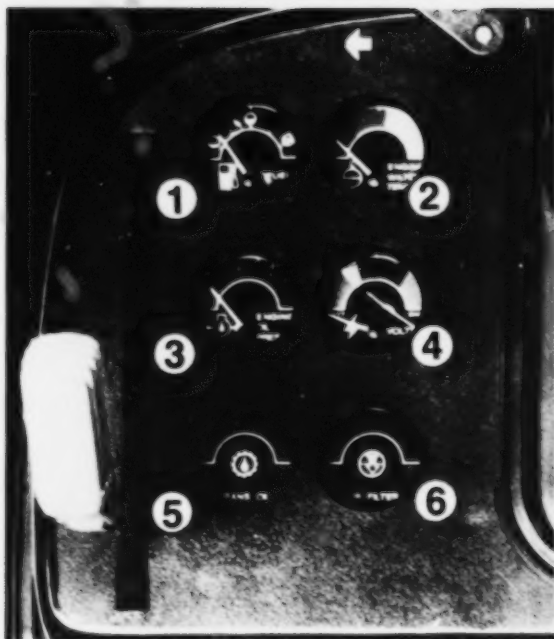


Fig. 10—Watch Your Instrument Panel For Trouble Signs

1. Fuel Gauge
2. Coolant Temperature Gauge
3. Engine Oil Pressure Gauge
4. Electrical Voltage Meter
5. Transmission Oil Temperature Light
6. Air Cleaner Restriction Light

SAFETY

Use safe procedures when performing machine maintenance. First, stop the engine (Fig. 9). Don't attempt to service your equipment when it is running, except when absolutely necessary, such as when timing the ignition or adjusting the carburetor.

Always think about what you are going to do before you do it. This is the most basic rule of safety. For example, don't remove the radiator cap until you have determined whether or not the coolant is still under pressure. Wait until it cools and the pressure drops—then remove the cap slowly.

STUDY YOUR OPERATOR'S MANUAL

Read your operator's manual carefully before attempting to operate or service your machine (Fig. 8). Follow the safety rules and you may avoid injury to yourself or others. Safe operation also reduces accidents which could damage equipment and require costly repairs or replacement. Where they apply, safety suggestions are included in this book.

WATCH YOUR INSTRUMENT PANEL

When you drive a machine, glance at the instrument panel from time to time (Fig. 10). The gauges and lights will tell you the condition of various engine systems and will signal you when they need maintenance. *Don't delay!* If a gauge gives you a warning, maintenance or repair is probably overdue and should be performed at once.

COVERAGE IN THIS BOOK

This book will cover not only tractors, but all engine-powered machines, such as self-propelled combines, windrowers, hay cubers, and forage harvesters.

Typical preventive maintenance is included for each system on a typical machine. For example, Chapter 2 will cover "Engine Intake and Exhaust Systems." Other chapters will cover lubricating, cooling, and electrical systems, as well as power trains, hydraulics, and other components such as cab air conditioning and accessories.

Although diesel engines presently outnumber gasoline engines in sales of new equipment, thousands of gasoline engines are still used regularly on combines, tractors, and other machines. Preventive maintenance is equally important on old as well as new equipment. Therefore, significant coverage is provided here for both engine types.

This book is not intended for making you, the reader, into a mechanic. Rather it is designed to give you a better understanding of the importance of preventive maintenance and the steps of performing maintenance jobs on farm machines. It is your responsibility to follow through and actually perform these steps and those in your operator's manual. Only then will you get the full benefits of this book.

CHAPTER QUIZ

1. Name three major benefits of good preventive maintenance.
2. What are the economic advantages of preventive maintenance?
3. Why should you refer to your operator's manual when performing maintenance?
4. What are the two most important things you must do before starting your machine each day?
5. What is the most basic rule of safety?

2

Engine Intake and Exhaust Systems



INTRODUCTION

An engine must "breathe" to create energy just as you do (Fig. 1). The intake and exhaust systems are the breathing apparatus of an engine. They carry the fuel-air mixture into the engine and remove the exhaust gases after combustion (Fig. 2).

INTAKE SYSTEM

The intake system supplies the engine with clean air of the proper quantity and temperature for good combustion.

The intake system has five basic parts:

- Air cleaners
- Turbocharger (if used)
- Air inlet
- Intake manifold
- Intake valves

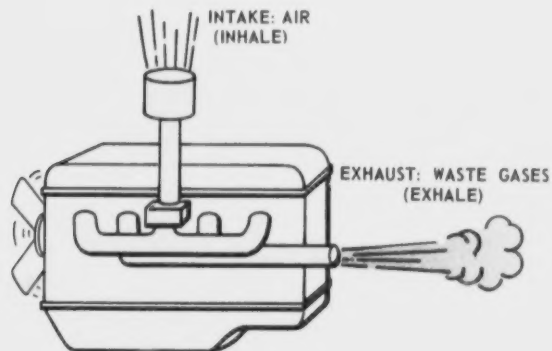
AIR CLEANERS filter dust and dirt from the air passing through them enroute to the carburetor (Fig. 3). Pre-cleaners prevent larger particles from reaching the air cleaner and lengthen service intervals.

TURBOCHARGERS (or Superchargers) increase power by forcing more air or fuel-air mixture into the engine cylinders than the engine could draw in by itself.

AIR INLET supplies fuel mixed with incoming air in the proper ratio for combustion, and also controls engine speed. (On spark-ignition engines, this mixture comes from the carburetor. On diesel engines, air only is provided, with fuel injected later at the engine cylinders.)

INTAKE MANIFOLDS transport the fuel-air mixture (pure air in diesel engines) to the engine cylinders.

Fig. 1—An Engine Must "Breathe"



INTAKE VALVES admit the air or fuel-air mixture to the engine cylinders for burning. They are normally opened and closed by linkage from the engine camshaft.

EXHAUST SYSTEM

The exhaust system collects the exhaust gases after combustion and carries them away. This is really three jobs: (1) Removing heat; (2) Muffling engine sounds; (3) Carrying away burned and unburned gases.

The exhaust system has three basic parts:

- Exhaust valves
- Exhaust manifold
- Muffler

EXHAUST VALVES open to release the burnt gases from the cylinder after combustion. The valves are normally opened and closed by the camshaft.

The **EXHAUST MANIFOLD** collects the exhaust gases and conducts them away from the cylinders.

The **MUFFLER** reduces the sound of the engine during the exhaust period.

A more detailed explanation of the intake and exhaust systems follows.

Fig. 2—Intake And Exhaust Systems

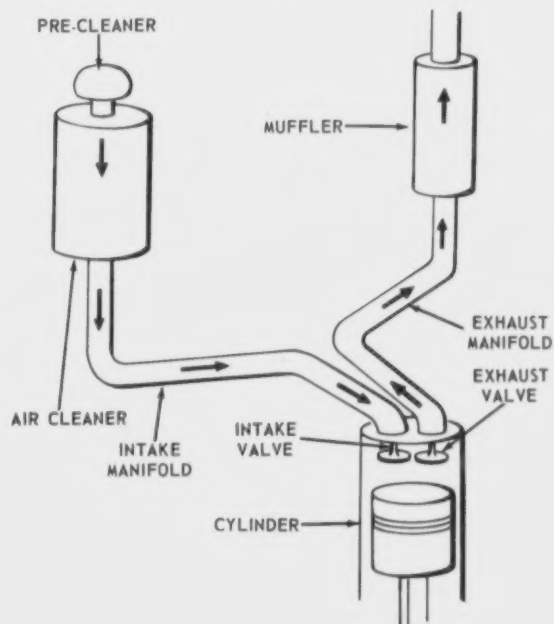




Fig. 3—Intake And Exhaust System Of A Typical Modern Engine

AIR CLEANERS AND AIR DUCTS

INTRODUCTION

The average engine mixes 9,000 to 10,000 gallons (liters) of air (by volume) with every gallon (liter) of fuel it consumes. Turbocharged engines use even more air. This amount of air can contain enough dirt to wear out the engine prematurely if the air is unfiltered, or if the air intake system leaks.

An air cleaner must have the capacity to hold material taken out of the air so that the engine can operate for a reasonable period before cleaning and servicing are necessary.

Multiple air cleaner installations are sometimes used where engines are operated under extremely dusty conditions or where two small air cleaners must be used in place of a single large cleaner.

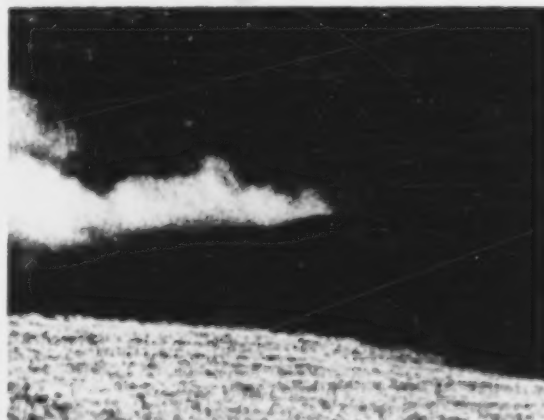


Fig. 4—Good Air Cleaner Maintenance Keeps Engines Going When Conditions Are Toughest

HOW DIRTY AIR CAN DAMAGE ENGINES

Consider these facts:

In some dusty environments, an engine can be ruined:

1. If an air hose comes off for only a few hours.
2. If a mere pinhole leak in a hose is left for a full season.

Keep this in mind when you think of air cleaning systems.

Agricultural engines operate in some very tough conditions (Fig. 4) and this makes air cleaner service doubly important.

TYPES OF AIR CLEANERS

The major types of air cleaners are:

- **Precleaners**
- **Dry element air cleaners**
- **Oil bath air cleaners**

Let's examine these more closely.

Precleaners

Precleaners (Fig. 5) are usually installed at the end of a pipe extended upward into the air from the air cleaner inlet. This places them in an area relatively free of dust.

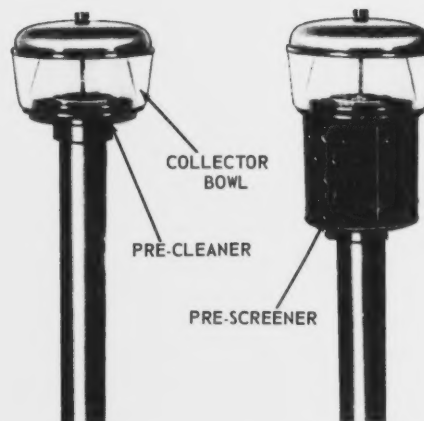
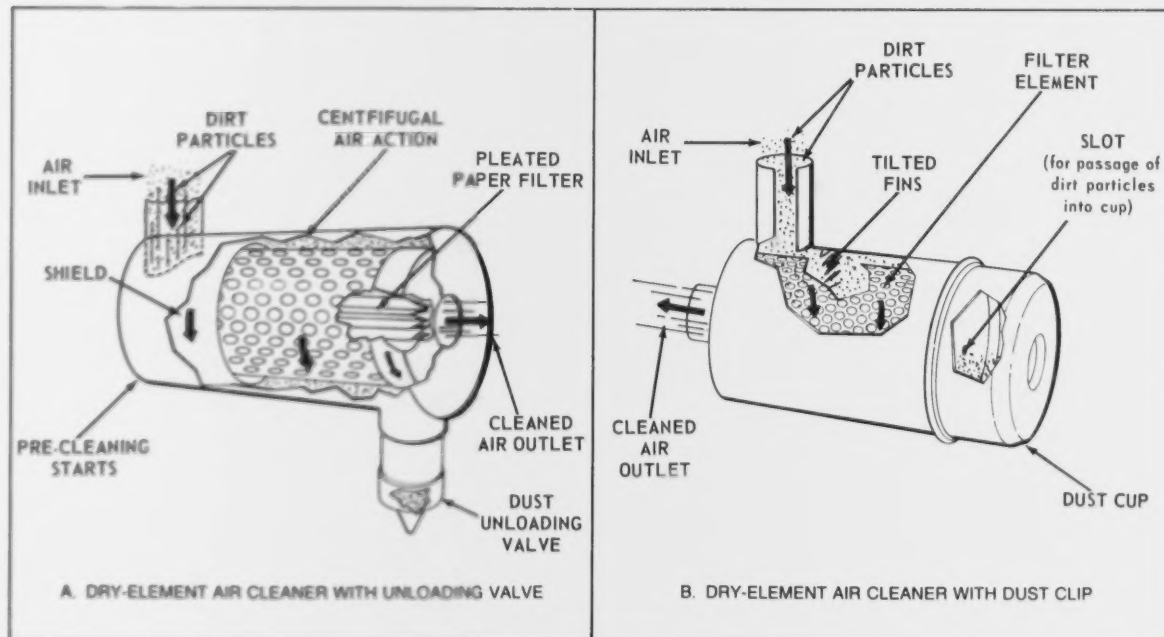


Fig. 5—Precleaner and Prescreener

Precleaners remove larger particles of dirt or other foreign matter from the air before it enters the main air cleaner. This relieves much of the load on the air cleaner and allows longer intervals between servicing.

Most precleaners have a *prescreener* (Fig. 5) which prevents lint, chaff, and leaves from entering the air intake. However, the prescreener can become plugged quickly under some conditions, thus preventing air from entering the air cleaner.

Fig. 6—Dry Element Air Cleaners—Two Types



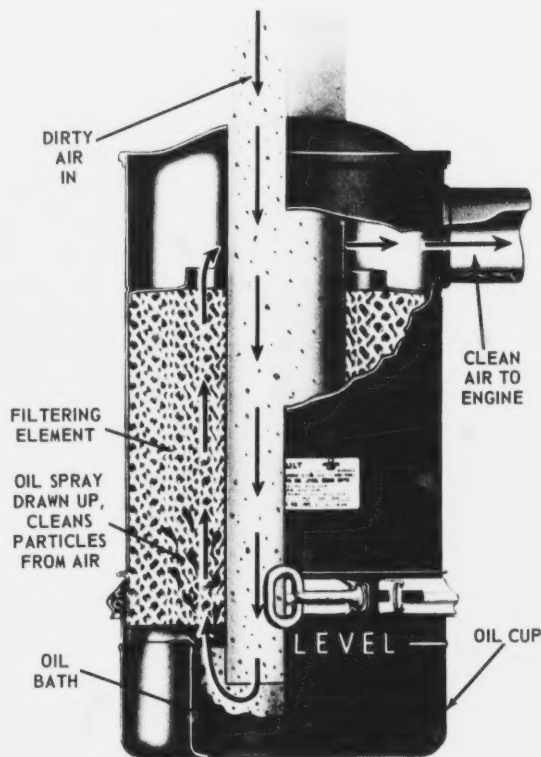


Fig. 7—Medium-Duty Oil Bath Air Cleaner

Dry-Element Air Cleaners

Two major types of dry-element cleaners are used at the present time (Fig. 6).

Dry-element air cleaners are built for two-stage cleaning:

- 1) *Precleaning*
- 2) *Filtering*

The first stage (precleaning) directs the air into the cleaner at high speed so that it sets up centrifugal rotation (cyclone action) around the filter element.

The cleaner shown in Fig. 6A directs the air into the *precleaner* so it strikes one side of the metal shield. This starts the centrifugal action which continues until it reaches the far end of the cleaner housing. At this point, the dirt is collected into a dust cap, or dust unloader, at the bottom of the housing.

The cleaner shown in Fig. 6B conducts the air past *tilted fins* which start the centrifugal (cyclone) action. When the air reaches the end of the cleaner housing, the dirt passes through a slot in the top of the cleaner and enters the dust cup.

In both types, this *precleaning* action removes from 80 to 90 percent of the dirt particles and greatly reduces the load on the filter.

The partially cleaned air then passes through the holes in the metal jacket surrounding the pleated-paper filter. *Filtering* is done as the air passes through the paper filter. It filters out almost all of the remaining small particles. This is the second stage of cleaning.

Some heavy-duty cleaners use a spiral rotor device for precleaning the air as shown in Fig. 3. Others have a small safety element built into the unit in case the main element fouls.

If the air cleaner has a *dust cup* (Fig. 6B) it should be emptied daily. If an *automatic dust unloader* is used in place of a cup (Fig. 6A), it is usually recommended that it be checked at least once daily to make certain it doesn't become clogged. The dust unloader is a rubber duck bill device that is held closed by engine suction while the engine is running. When the engine stops, the flaps open so dirt can drop out. Check the flaps regularly to see that they close during operation to prevent dust from being sucked into the engine.

Some dry-element cleaners are equipped with a *vacuum gauge* or *restriction indicator* to show when the filter needs cleaning (see inset, Fig. 13). The indicator is attached to the intake manifold of the tractor. As the *dirt accumulation builds up on the filter*, air flow is restricted. This increases the suction in the intake manifold and causes the indicator to show red. To maintain engine operating efficiency, it is important that the filter be serviced at once.

Oil Bath Air Cleaners

Medium-duty oil bath air cleaners (Fig. 7) draw air down a center tube where it strikes the surface of oil in a partly filled cup. The impact causes a mixture of air and oil spray to be carried up into the element of baffles and wire mesh. The separating element breaks up the dust-laden air and fine dust particles are trapped by the oil film. The particles are then washed down as the oil later drains back into the cup. Clean air continues through the element and on to the engine.

The washing down of the oil keeps the filter element fairly clean.

The major services are (1) to keep the oil cup filled to the proper level with the correct weight of oil, and (2) to replace the oil when it gets dirty or thickens, reducing its ability to clean particles from the air.

However, at least once each year, the air cleaner should be disassembled and the filter element cleaned in solvent.

NOTE: Today's detergent oils may hold the dirt in suspension. For this reason the need for oil cup service cannot be determined by the layer of dirt which has

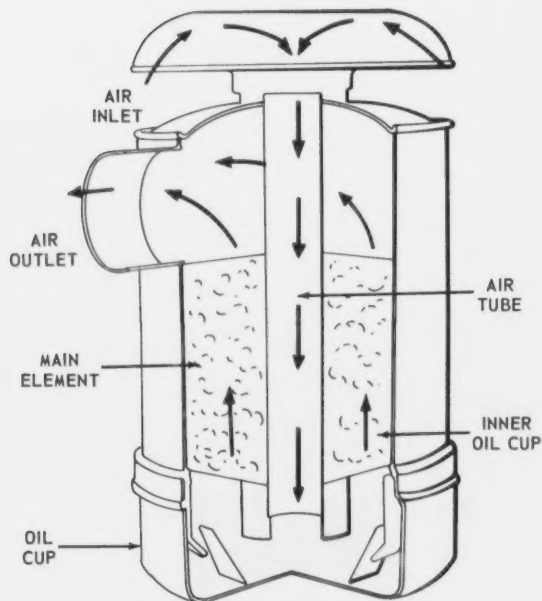


Fig. 8—Heavy-Duty Oil Bath Air Cleaner

settled into the bottom of the cup. Instead, see if the oil has thickened due to dirt.

Some medium-duty air cleaners are fitted with an oil trap. This trap catches the oil which otherwise would be thrown out of the cleaner when the engine backfires.

Heavy-duty oil bath air cleaners (Fig. 8) operate the same as medium-duty ones. They are used on larger engines, especially diesels, because these engines use more air.

IMPORTANCE OF SERVICE

Air cleaner efficiency depends upon your performing proper maintenance and service.

Oil bath cleaners must be properly maintained or the oil cup will become filled with sludge, preventing the screens and elements from cleaning the air properly. This will restrict air flow to the engine (the same effect as choking the engine) and may allow dirty air to enter. Restricted air flow through the air cleaner will eventually cause incomplete combustion, increased carbon formation, and crankcase oil dilution.

Clean air and unrestricted air flow help conserve fuel and enable the engine to produce more power per unit of fuel burned.

Leaks in the connecting pipes, loose hose connections, or damaged gaskets which permit dust-laden air to enter the engine, can defeat the purpose of the air cleaner. *Remember: Dirty air going directly into an engine cylinder is abrasive and will cause premature wear of moving parts.*

AIR CLEANER SERVICES

"How do I know when to service my engine's air cleaner?" Check the operator's manual.

No hard and fast rule can be given for servicing an air cleaner since this depends upon the type of cleaner, condition of air, and type of application.

Normal service intervals are designated by the manufacturer, but frequent inspection can tell whether or not this is adequate for the conditions under which the engine is operating.

A cleaner operating in severe dust conditions will require more frequent service than one operating in clean air.

Always refer to your operator's manual for service information.

Materials Needed

For oil-bath air cleaners:

1. Wrenches for removing air cleaner housing (if required).
2. Cleaning cloths.
3. Container to catch waste oil.
4. Bucket of cleaning solvent (*not* gasoline).
5. Clean oil of the same viscosity used in the crankcase.

For dry-element air cleaners:

1. Wrenches for removing air cleaner cover (if required).
2. Compressed air source (not over 30 psi; 205 kPa of pressure).
3. Bucket of warm water with a nonsudsing detergent.
4. Water source (not over 40 psi; 275 kPa of pressure).
5. Goggles or glasses for eye protection.

Servicing Precleaners

Every 10 hours, check the precleaner bowl. If dirt has built up to the line, remove the bowl (Fig. 9) and empty it.

If the unit has a pre-screener (see Fig. 5), check it daily. Blow or brush off any chaff or other foreign matter.

If the precleaner unit is allowed to clog, a greater load is placed on the main air cleaner.

Servicing Oil Bath Air Cleaners

Every 10 hours of operation, check the oil cup for correct oil level and for dirt accumulation.

NOTE: *Under extremely dirty conditions, check the oil cup twice daily.*

Service the air cleaner as follows:

1. Loosen oil cup and remove from filter (Fig. 10).



Fig. 9—Emptying Precleaner Dust Bowl

Don't try to remove cup with engine running. This allows unfiltered air to enter directly.

2. Check depth of sediment deposit in outer chamber.

If *sediment* in the outer compartment is about $\frac{1}{2}$ inch (12 mm) deep, proceed with the remaining steps. (Some manufacturers recommend cleaning when $\frac{1}{4}$ inch (6 mm) of dirt has accumulated. Check your operator's manual for recommendations.)

If the *oil has thickened*, even though the dirt depth may not be as high as $\frac{1}{2}$ inch (12 mm), change the oil. Thickened oil acts as a choke on your engine causing it to use more fuel. Fuel consumption may increase as much as a gallon (4 liters) or more per hour.

There is also a possibility of drawing dirt-laden oil into the carburetor, then into the engine, where it acts as a grinding compound causing extremely fast wear.

With today's high-detergent oils, dirt may never settle to the bottom of the cup, so watch for thick oil as your signal that the oil needs to be changed.

If there is *water in the cup*, you will probably find the air intake cap has been removed, allowing rain to enter. Proceed with cleaning the cup and be sure to replace air intake cap. Water interferes with effective air cleaning action.

3. If cup needs cleaning, throw away dirty oil, scrape and then wash inner and outer cups with clean diesel fuel (Fig. 11).

CAUTION: Don't use gasoline or other highly inflammable liquids such as naphtha or benzene.

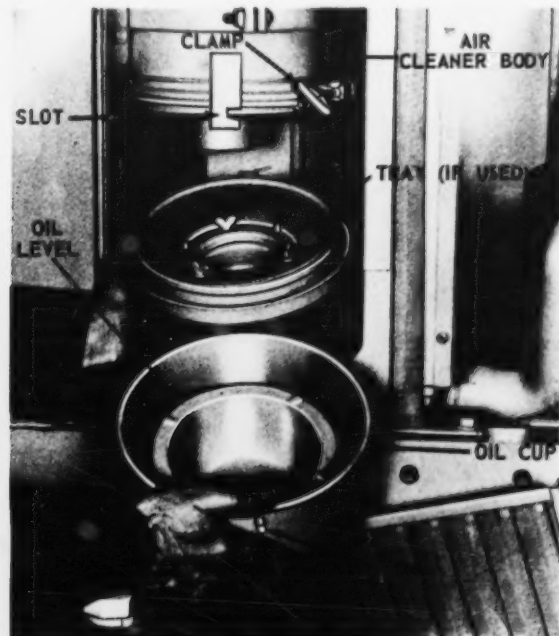


Fig. 10—Removing Oil Cup From Air Cleaner

Remove all caked dirt from bottom of cup.

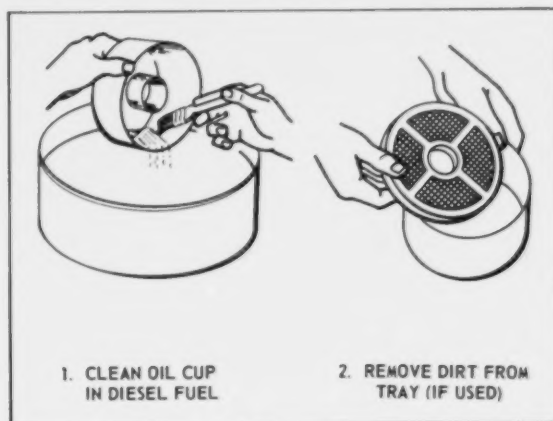
Also clean dirt from tray (if used). See Fig. 11.

4. Check air intake pipe (air stack) for dirt accumulation.

This will not need cleaning often, but it is good practice to check it each time the oil cup is serviced.

If dirty, swab it out with your cleaning material. The more dirt you allow to accumulate in the stack, the more it acts as a choke to air flow and increases fuel consumption.

Fig. 11—Cleaning Oil Cup And Tray



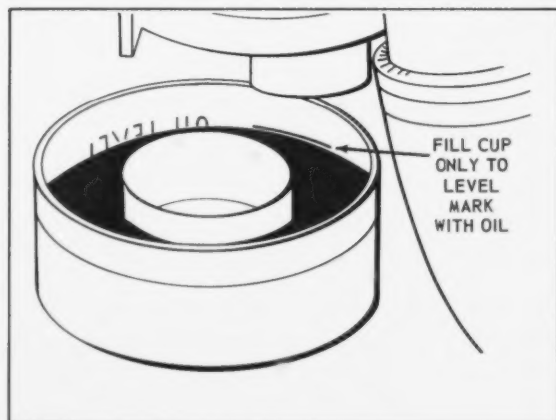


Fig. 12—Fill Oil Cup To Level Mark

5. *Refill cup with oil to "oil level" mark (Fig. 12).* Most operator's manuals recommend the same weight as used in the engine crankcase.

If you use an *oil that is too heavy*, the washing action is lessened. It also acts as a choke on the engine and increases fuel consumption.

Oil that is too light will pull into the engine. This lowers the oil level in the cup until the cleaner is not efficient. With diesel engines, the oil is used as fuel, causing the engine to run wild. When this happens, you have no control of engine speed.

Don't use old crankcase oil. It may contain unburned fuel which evaporates quickly and lowers the oil level in the cup. It also contains dirt which limits washing action.

An additive oil can be used, but it is of no particular benefit for this purpose.

Don't overfill the oil cup. On spark-ignition engines it increases fuel consumption and causes loss of power. On diesel engines, the oil may be drawn into the engine and used as fuel, causing the engine to run wild.

6. *Replace oil cup (and screen tray, if used) and tighten clamp.*

7. *Check air duct between cleaner and carburetor (or intake manifold on diesel engines) for holes or loose clamp connections.*

Air entering the engine here bypasses the air cleaner. Dirt particles pass directly to the engine, causing rapid wear.

8. *Check air inlet screen, or precleaner, and remove trash if necessary (see above).*

Oil-Bath Cleaning

At least once each year, completely disassemble and clean the air cleaner system. This is vital for long engine life.

Over long periods, dirt collects in the air cleaner center tube and in the lower part of the filter element. Dirt chokes off the air supply to the engine. Cleaning the system at least once each year pays off in reduced fuel consumption and more engine horsepower.

Swab out the center tube with a cloth soaked with diesel fuel. If the filter element is dirty, wash it in diesel fuel or solvent. Drain all parts and wipe dry. Then reassemble the air cleaner.

When assembling, be sure all hoses and gaskets are in good condition and that all connections are tight.

Servicing Dry-Type Air Cleaner

If the dry air cleaner has a dust cup, empty it daily. If an automatic dust unloading valve (Fig. 16) is used in place of a dust cup, check it daily for clogging.

Service the dry air cleaner element every 50 hours or at the following times:

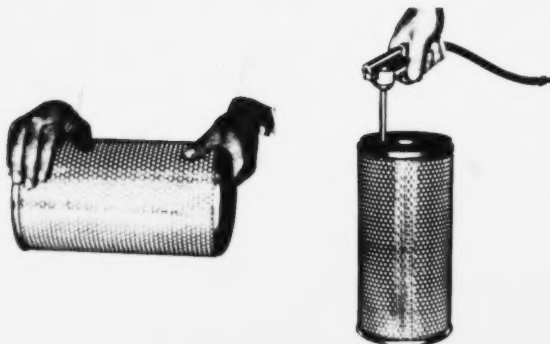
1. *Units with restriction indicator:* Clean element whenever indicator glows or signals a restriction. (Some indicators may stick, so watch conditions and hours of operation carefully.)

2. *Units without indicator:* Clean element at recommended intervals—more often during dusty or unusual operation.

NOTE: Avoid too-frequent cleaning of dry-type air cleaners as cleaning always presents the danger of damaging the filter element.

Fig. 13—Dry-Element Air Cleaner





PATting THE ELEMENT

BLOWing OUT THE ELEMENT

Fig. 14—Cleaning The Dry Element

When the engine smokes too much or loses power, there may be a restriction in the dry air cleaner.

Dusty Element: Remove filter element and tap element *gently* on heel of hand to remove dust. Rotate element while tapping it. **Never tap element on hard surface** such as wheel of machine, as this may dent it and create an opening for dirty air.

If tapping does not remove the dust, use a compressed air cleaning gun (pressure not to exceed 30 psi; 250 kPa) to clean the element (Fig. 14). Direct clean dry air up and down pleats, *blowing from inside to outside*. Wear goggles or glasses to protect eyes from dust and dirt.

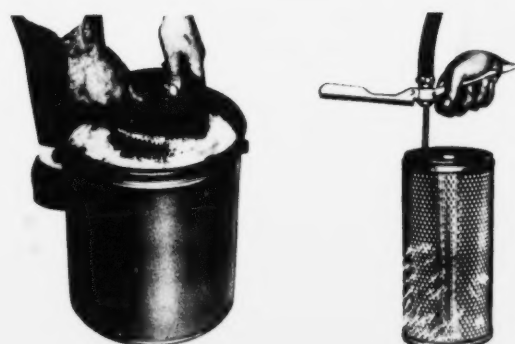
IMPORTANT: BE CAREFUL NOT TO RUPTURE THE ELEMENT. Do not try to clean off outside of air cleaner with an air hose as it may clog it.

To clean with water: First blow out dirt with compressed air as described above. Then attach garden hose to cleaning gun and flush remainder of dirt from inside to outside of element. *Be sure to allow element to dry before installing it.* (It is a good idea to have two elements on hand in case one is damaged. Also, the completely dry element can then be installed each time.)

Oily or Sooty Elements: Blow out the dust with compressed air or flush with clean water. Soak and gently agitate element in a solution of lukewarm water and commercial filter element cleaner or an equivalent nonsudsing detergent (Fig. 15).

Rinse element thoroughly with clean water from hose (Fig. 15) having maximum pressure of 40 psi (275 kPa) or less. Shake excess water from element and allow it to air dry (requires 24 hours or longer). Protect from freezing.

IMPORTANT: Never wash a dry element in fuel oil, gasoline, or solvent. Never use compressed air to dry the element.



WASHing THE ELEMENT

RINSing THE ELEMENT

Fig. 15—Washing And Rinsing The Dry Element

After cleaning the element, inspect it for damage by placing a light inside it. Discard any element that shows the slightest damage.

Inspect filter element gasket for damage. Replace element if gasket is damaged or missing.

IMPORTANT: Replace the filter element:

- If damaged.
- After a recommended service period (such as one year or six washings).
- When attempts to clean it fail.

Thoroughly clean inside of cleaner body with a clean, damp cloth. Install element in cleaner body, gasket and fin end first. Be sure gasket is in place.

Draw cover tight on cleaner. *Reset restriction indicator (if used).*

Servicing Safety Element (If Used)

Some large engines have a safety element in case the primary element ruptures and fails. Normally, these elements are not cleaned, only replaced once each season. However, check the condition of the safety element during service. If it is very dirty, the primary element has probably failed and both elements must be replaced to maintain efficient engine operation.



Fig. 16—Dry Air Cleaner Dust Unloading Valve

Servicing Dust Unloading Valve (If Used)

Every 10 hours, inspect rubber dust unloading valve (if used) (Fig. 16). Squeeze the rubber end of the valve to make sure it is still open and free of clogging. Be sure valve closes when engine is running. This prevents dirt from being sucked into the engine through the valve. Clean the valve if necessary. Replace if cracked or worn.

Checking Air Cleaner Connections

Every 500 hours of operation, make a general check of all connections from the air cleaner to the engine (Fig. 17). Remove the hood or cowl if necessary. Tighten any clamps on hoses or tubes to prevent dirty air from entering engine through loose connections.

This concludes our air cleaner service story. Remember that dry air cleaners are as effective as oil bath types, but they do require careful handling and more inspection for breaks or holes which could allow dirty air to harm the engine.

Fig. 17—Checking Air Cleaner Connections

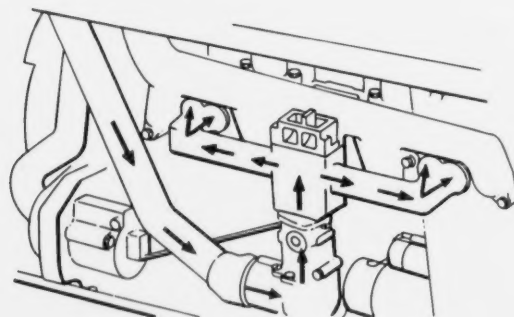
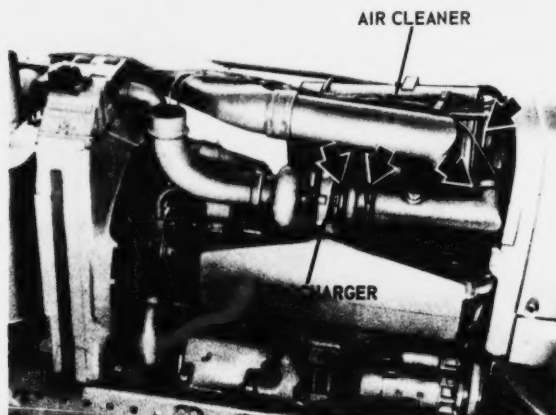


Fig. 18—Typical Intake Manifold (Spark-Ignition Engines)

INTAKE MANIFOLD

On gasoline engines, the fuel-air mixture is carried from the carburetor to the engine intake valves by the manifold (Fig. 18).

Diesel engine intake manifolds are similar to spark-ignition engine manifolds except that they do not require heat (to vaporize fuel) and are usually located on the side of the engine opposite the exhaust manifold.

LP-gas fuel vaporizes at normal temperatures so a mixing valve and converter are used instead of a carburetor.

Even though heat transfer from the exhaust manifold is not required to vaporize fuel, a similar intake system (following the carburetor) can be used for LP-gas as for gasoline systems.

Fig. 18 illustrates a typical gasoline engine manifold. Heat is supplied either by having the exhaust manifold touch the intake manifold at various spots or by having exhaust passages built into the intake manifold.

SERVICING INTAKE MANIFOLDS

Every 50 hours, tighten the bolts and check the intake manifold for restrictions or air leaks.

TURBOCHARGERS

The power delivered by an internal combustion engine is determined by the amount of fuel and air which can be compressed into each cylinder. The more the fuel-air mixture, the more power the engine develops.

The **turbocharger** is a type of air pump and gives the engine a higher overall compression pressure than it would normally have (Fig. 19).

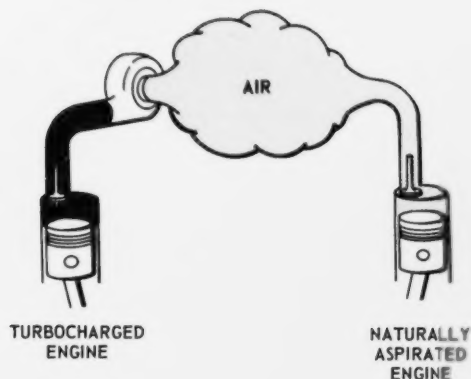


Fig. 19—Turbocharger Compresses More Air Into Engine For Greater Combustion And Power

It does this by taking intake air, compressing it, and forcing it into the engine cylinders (Fig. 20).

Pumping air into an engine also aids in getting exhaust gases out. This too results in more efficient combustion.

Some engines are designed and built for turbocharging. If an engine is not equipped with a turbocharger, it may be damaged if one is added. Be sure to check with your dealer before you try to turbocharge an engine yourself.

NOTE: Turbochargers operate at speeds of 40,000 to 130,000 rpm, or more. This means they must have adequate lubrication at all times and air must be clean to avoid excessive wear.

SERVICING TURBOCHARGERS

Periodically make the following inspections:

1. Inspect the mounting and connections of the turbocharger to be certain they are secure and there is no leakage of oil or air.
2. Check the engine crankcase vent to be sure there is no restriction to air flow.
3. Operate the engine at approximate rated output and listen for unusual turbocharger noise. If a shrill whine (other than normal) is heard, stop the engine immediately. The whine means that the bearings are about to fail. Have the turbocharger removed for inspection.

Do not confuse the normal whine heard during "run down" as the engine stops with a bearing failure during operation.

Other unusual turbocharger noises could mean improper clearance between the turbine wheel and housing. In these cases, a serviceman should remove the turbocharger for inspection.

4. Check the turbocharger for unusual vibration while

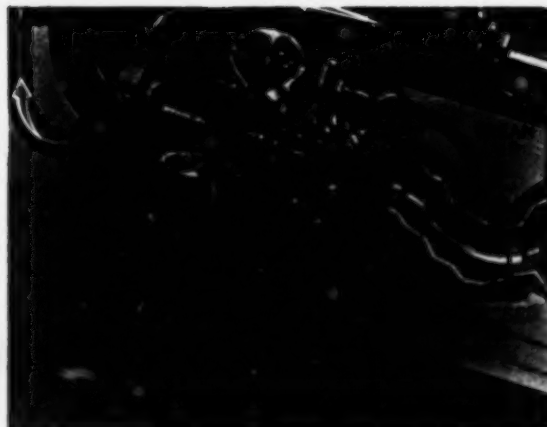


Fig. 20—A Turbocharger

engine is operating at rated output. If necessary, have the turbocharger removed for inspection.

5. Check engine under load conditions. Excessive exhaust smoke indicates an incorrect fuel-air mixture. This could be due to engine overload or turbocharger malfunction.

NOTE: Clean air is vital to turbochargers, as dirty air can pit the rotary vanes and alter its balance.

INTAKE AND EXHAUST VALVES

The valves let fuel and air in and exhaust gases out of each engine cylinder during the combustion cycle.

OPERATION OF VALVES

You, as a machine operator, should understand how the intake and exhaust valves work.

The engine must take in fuel-air and expel spent gases at precise intervals. The valves do this job by opening and closing the intake and exhaust ports to the cylinder.

The sequence of valve operation for a typical four-stroke cycle engine is shown in Fig. 21. Each cylinder has two valves—intake and exhaust.

1. During the intake stroke, the intake valve opens as shown, allowing the fuel-air mixture to enter the combustion chamber.
2. During compression and power strokes, both valves are closed to seal in the combustible mixture.
3. During the exhaust stroke, the exhaust valve opens, allowing gases to be exhausted.
4. At the end of the exhaust stroke, the intake valve opens, beginning another cycle.

The camshaft (Fig. 22) is turned by the engine crankshaft. A lobe (cam) on the camshaft causes the cam follower and push rod to push the valve open. The

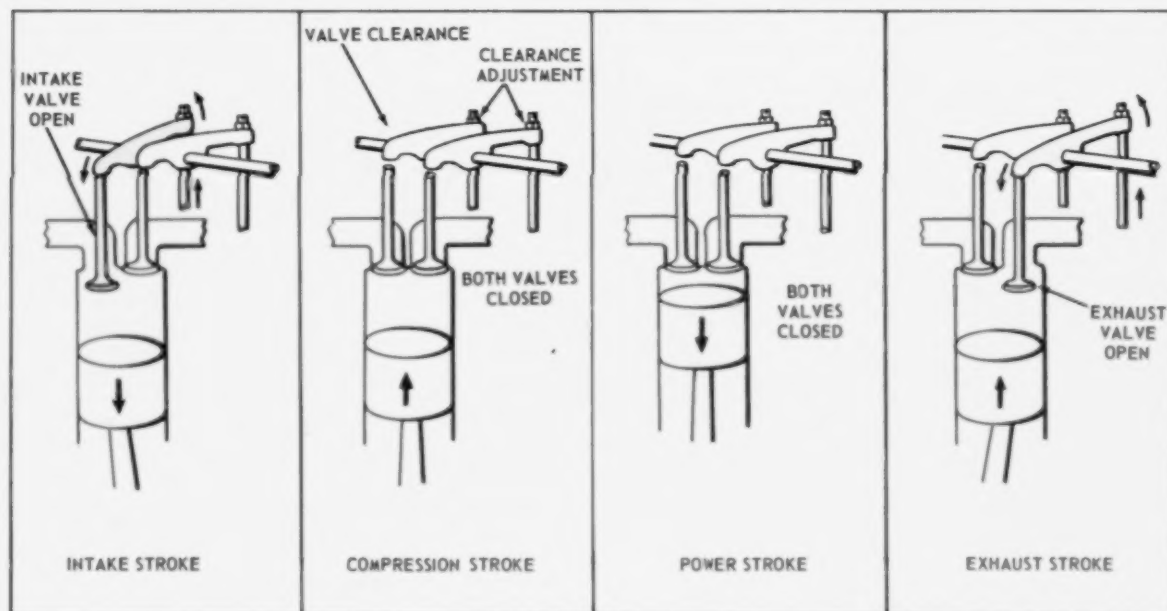


Fig. 21—Valve Operation In A Four-Stroke Cycle Engine

spring closes the valve when the cam allows the push rod and cam follower to return to the low side of the cam. Cam movements are designed to open or close the valves at the right moment.

IMPORTANCE OF VALVE CLEARANCE

If proper valve maintenance is not performed, the engine will not work efficiently and may be damaged.

When valves are properly adjusted, there is normally a small clearance between the valve stem and the end of the rocker arm. (This clearance is sometimes referred to as "valve clearance," "valve lash" or "tapet clearance.")

Valve clearance allows for the heat expansion of valve operating parts. Without clearance, the heated parts would cause the valves to stay partly open during operation and engine would lose compression and power (Fig. 23).

This valve clearance is small, varying from approximately 0.006 inch to 0.030 inch (0.15 to 0.75 mm). The engine manufacturer recommends a definite clearance for each engine model. The valve clearance may vary, depending on the engine model and whether the engine should be hot or cold during adjustment (some engines run hotter than others).

Too little valve clearance throws the valves out of time. This causes valves to open too early and close too late. Also, valve stems may lengthen from heating

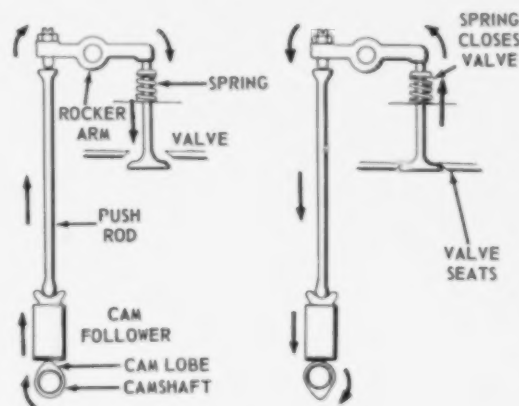


Fig. 22—Typical Valve Operating Mechanism

and prevent valves from seating completely (Fig. 23). Hot combustion gases rushing past the valves cause overheating because the valves seat so briefly or so poorly that normal heat transfer into the cooling system does not have time to take place. This causes burned valves (Fig. 24).

Too much valve clearance causes a lag in valve timing which throws the engine out of balance. The fuel-air mixture is late entering the cylinder during the intake stroke. The exhaust valve closes early and prevents waste gases from being completely removed.

The valves themselves also become damaged. When valve clearance is properly adjusted, the camshaft

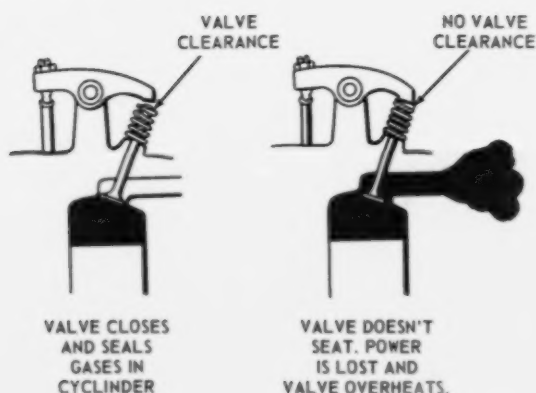


Fig. 23—Importance of Valve Clearance

slows the speed of valve movement as it closes. But with too much clearance, the valves close with great impact, cracking or breaking the valve (Fig. 25) and scuffing the cam and follower.

Summary: Why Proper Valve Adjustment Is Important

- The engine will use fuel more efficiently.
- The engine will start more easily.
- Maximum power will be achieved.
- Valves will give longer service.
- Overheating of the engine is less likely to occur.

TOOLS AND MATERIALS NEEDED

To make valve clearance adjustments, the following is needed:

1. Set of box and wrenches (inch or metric, as required).

Fig. 24—Valve Burned From Too Little Valve Clearance

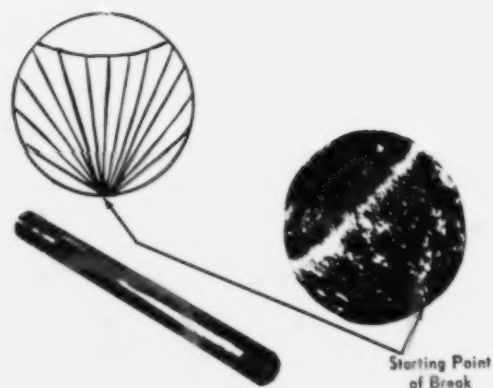


Fig. 25—Valve Broken From Too Much Valve Clearance

2. Set of open end wrenches (inch or metric, as required).
3. Spark plug wrench (inch or metric, as required).
4. Feeler gauge (inch or metric, as required).
5. Torque wrench and socket set (inch or metric, as required).
6. Screwdriver
7. Clean cloths
8. Bucket of cleaning solvent (*not* gasoline).
9. Container for nuts and cap screws.
10. New gasket to replace old valve cover gasket.

PREPARING FOR VALVE TAPPET ADJUSTMENTS

Check valve tappet adjustments every 500 hours of operation, or at intervals indicated in your operator's manual. Before adjustments can be made, you must determine how you are going to make them. Some manufacturers recommend that valve adjustments be made by an authorized dealer or trained mechanic. Read your operator's manual, or obtain a technical service manual for your engine for step-by-step procedures. Many agricultural engines are enclosed under fuel tanks and engine shrouds. Often these parts must be removed before the valve cover or rocker arm cover can be removed to obtain access to the valves (Fig. 27).

NOTE: If you are adjusting valves for the first time, have someone help you, or practice on an older engine or a small engine until you become proficient.

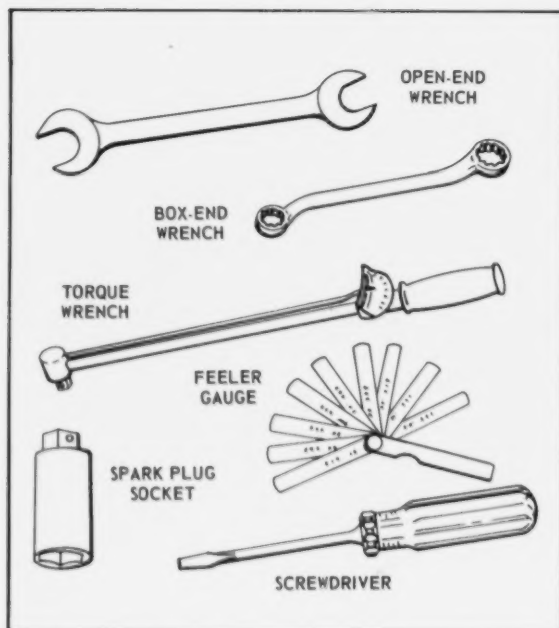


Fig. 26—Tools Needed For Adjusting Valve Tappet Clearances

Let's assume that you must remove parts which interfere with removal of the valve cover.

1. Remove parts as necessary (Fig. 27).
2. Clean dirt from the valve cover and from around the spark plugs.
3. Remove the nuts or cap screws which hold the cover in place.
4. Carefully remove the valve cover (Fig. 28). Strike

Fig. 27—Parts That May Need To Be Removed Before Valve Cover Is Removed

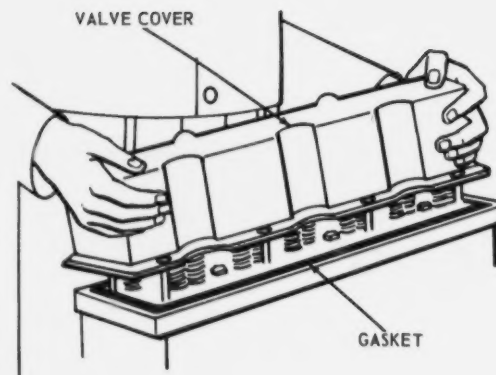
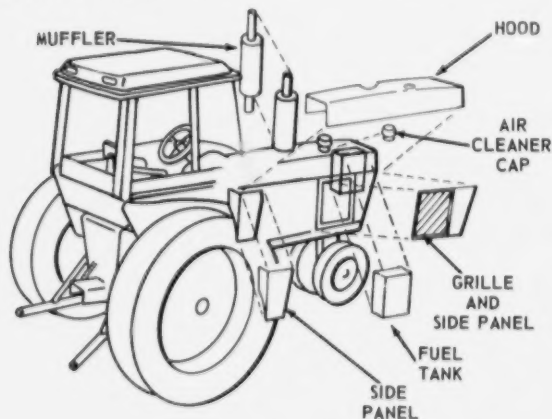


Fig. 28—Removing Engine Valve Cover

the cover on one side and then on the other with the palm of your hand. Don't worry about damaging the gasket because you should replace it with a new one each time the cover is removed.

5. To prevent accidental starting of the engine during valve adjustment, take the following precautions:

- a. Disconnect the center terminal wire to the distributor (Fig. 29).
- b. OR, remove spark plugs.

With *diesel engines*, shut off the fuel supply to the injection pump.

CAUTION: If these precautions are not followed, the engine could start during valve adjustment and cause serious injury to you.

ADJUSTING VALVE TAPPET CLEARANCE

Since most manufacturers recommend that the valve clearance adjustment be made when the engine is stopped, we will cover procedures for adjusting valves with the engine cold. Refer to your operator's manual for recommendations.

Unless your operator's manual gives a shortcut, you must rotate the engine crankshaft each time a different pair of valves is to be adjusted. We will show adjustment of valves using this method, which works for all engines.

1. Retorque Cylinder Head

Check the tightness of the cylinder head nuts or bolts with a torque wrench (Fig. 30). Refer to the operator's manual or service manual to determine the proper torque to apply and the sequence. Do this *before* adjusting valves because valve clearance may be changed if you tighten the head after adjustment of the valve clearance.



Fig. 29—Disconnecting Center Terminal Wire To The Distributor

2. Set No. 1 Cylinder At TDC

Turn the crankshaft slowly until piston in number one cylinder is at top dead center (TDC) of its compression stroke. Use one of the methods described below to determine this position. Usually, the number one cylinder is next to the radiator on vertical engines, or next to the flywheel on horizontal engines.

To rotate the crankshaft use one of the following methods: "Bump" the engine with the starter, turn the crankshaft with a special tool, or if the spark plugs are removed, you may be able to turn the fan enough to rotate the crankshaft.

With the piston in the correct position (TDC) of the compression stroke, both the intake and exhaust valves are closed. The cam followers are riding on low sides of the cam lobes.

There are two methods for determining when number one piston is at TDC of compression stroke:

a. *For both spark-ignition and diesel engines, you can proceed as follows:*

Refer to your operator's manual to determine correct timing marks. Several markings may be present. As you turn the crankshaft to top dead center (TDC), watch the intake valve on the number one cylinder. When it closes, turn the crankshaft one-half turn. The TDC mark should be in line with the pointer. Check both the intake and exhaust rocker arms of cylinder number four (or number six if a six-cylinder engine). Both arms should be "rocking" (exhaust valve closing

START TIGHTENING
BOLTS AT CENTER
OF HEAD

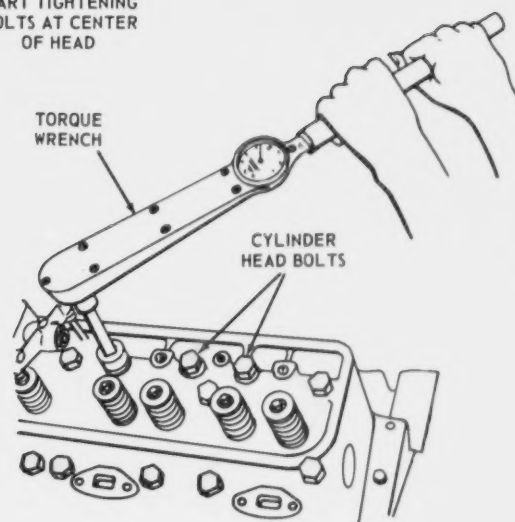


Fig. 30—Tightening Cylinder Head Bolts Before Adjusting Valves

and intake valve opening) when the number one piston is at TDC.

b. *For spark-ignition engines only, you can proceed as follows:*

To prevent engine from starting, remove spark plugs. Be sure the coil wire is inserted into the center of the distributor. Position number one spark plug wire about 1/4 inch from the engine block. Turn the crankshaft slowly until a spark jumps the gap.

Place your thumb over the spark plug opening and crank the engine until you reach the end of the compression stroke—when no further pressure is felt. The piston should now be at TDC. (A special whistle can also be used. By inserting it in No. 1 cylinder port, a whistle is heard when TDC is reached.)

3. Select Feeler Gauge

Select the correct feeler gauge thickness according to your operator's manual. Both the intake and exhaust valves may require the same clearance; however, on some engines the exhaust valve requires more clearance than the intake valve because it normally runs hotter.

4. Check Clearance With Feeler Gauge

Insert the gauge between the valve stem and the rocker arm of both valves (Fig. 31). If the two valves require different clearances, be certain to identify which valve is the exhaust and which is the intake. Your operator's manual or technical manual will show this.

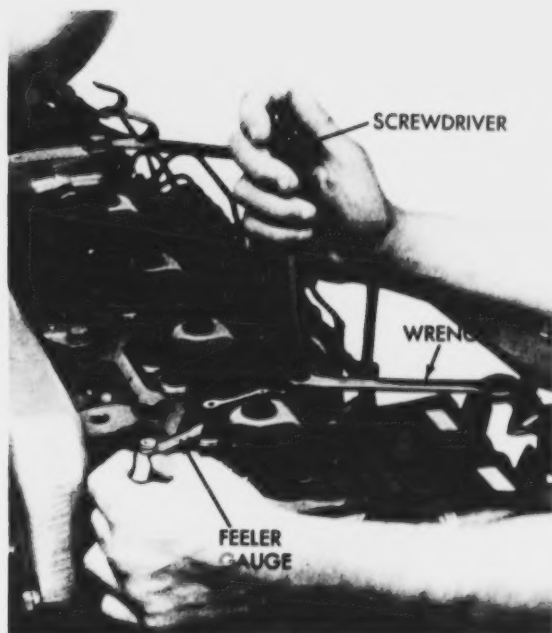


Fig. 31—Adjusting Valve Clearance

As you slide the gauge in and out of the clearance, you should feel a slight drag if the gap is correct. Check with the next size thicker and thinner gauges. The thicker gauge should be difficult to insert, and the thinner gauge should be easy to insert.

If the clearances are correct, proceed with step 8.

If the clearance requires adjusting, proceed with the steps that follow.

5. Adjust Two Valves

- Loosen the lock nuts on the two rocker arm adjusting screws (Fig. 31).
- Turn adjusting screws until feeler gauge slips with a slight drag.
- Hold the adjusting screws from turning and tighten the lock nuts. Recheck the clearance as described in step 4. You may have to readjust the clearance.

6. Determine Which Cylinder Fires Next

The firing order will tell you this. Usually the firing order appears on the side of the engine. If it does not, refer to your operator's manual. Fig. 32 shows the firing order for most agricultural engines.

7. Set Next Cylinder At TDC

Turn the crankshaft until the next cylinder to fire is at top of its compression stroke. With 2- and 4-cylinder engines, turn the crankshaft one-half turn. With a 6-cylinder engine, turn the crankshaft one-third turn. (On 8-cylinder engines, turn one-fourth turn.)

Fig. 32 shows that this much rotation will bring the next piston into correct position.

8. Adjust Valve Clearance

Adjust valve clearance following the same procedures as used on the number one cylinder.

9. Set Remaining Valve Clearances

Proceed in the same manner as above with the remaining cylinders, rotating the engine for each pair of valves.

NOTE: For 8-cylinder engines, the firing order is 1-8-4-3-6-5-7-2. These engines, such as V-8's, can normally be adjusted as follows: Place engine in No. 1 TDC position. Then adjust the following valves. Exhaust—1, 3, 4, 8. Intake—1, 2, 5, 7. Crank the engine one revolution to No. 6 TDC position, then adjust all remaining valves: Exhaust—2, 5, 6, 7. Intake—3, 4, 6, 8.

REASSEMBLY AFTER VALVE ADJUSTMENTS

- Clean and install spark plugs (see page 107).
- Before installing valve cover, start engine to check lubrication of rocker arms. You may have to install some of the parts you removed if they are required to run the engine. Be certain an ample supply of oil is being delivered to all rocker arms. If your operator's manual recommends that you check the valve clearances again with the engine thoroughly heated, do this now. A different set of clearances must be used because as the engine heats, the valve stems lengthen and less clearance is needed.
- Position new gasket on the cylinder head.
- Install valve cover. Be certain that the gasket fits properly under the edges of the valve cover or oil will leak by and increase oil consumption.
- Install all remaining parts.

EXHAUST MANIFOLDS AND MUFFLERS

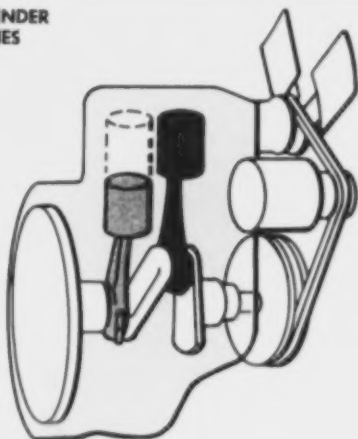
EXHAUST MANIFOLDS

Exhaust manifolds receive burned gases from each cylinder and carry them away from the engine (Fig. 33). Some heat from the exhaust manifold on gasoline engines is used to maintain the intake manifold at the proper temperature.

The exhaust ports in the engine and the passages in the exhaust manifold are large to allow free flow and expansion of the hot escaping gases. This is important because it permits better removal of gases or scavenging of the engine cylinders.

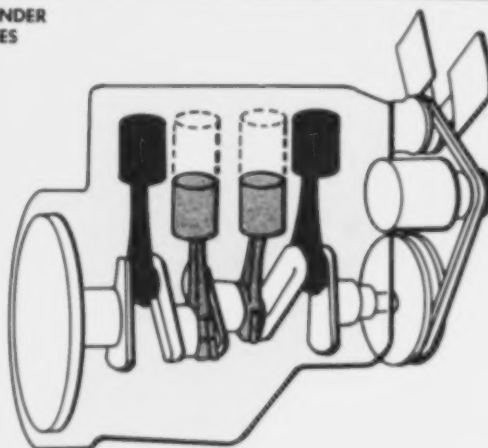
Fig. 32—Firing Order of 2-, 3-, 4-, 6-, and 8-Cylinder Engines
(For Modern Farm Machines)

**2-CYLINDER
ENGINES**



1-2 FIRING ORDER
FOR ALL SPARK-IGNITION
OR DIESEL ENGINES

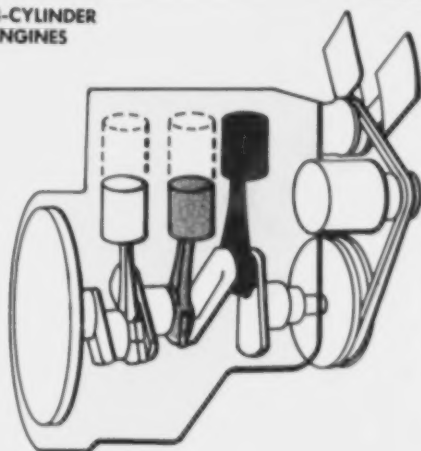
**4-CYLINDER
ENGINES**



1-2-4-3 FIRING ORDER
(Spark-Ignition or Diesel)

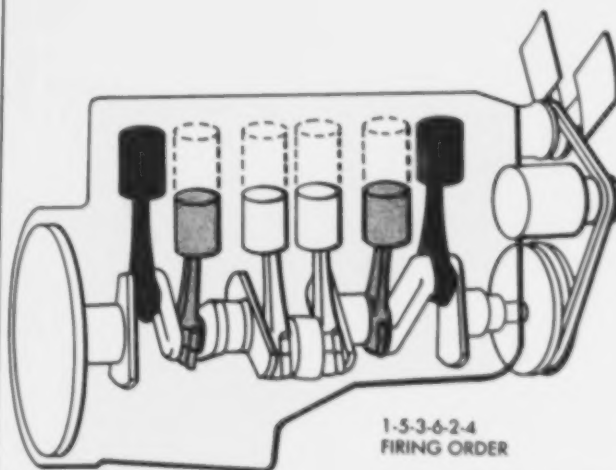
1-3-4-2 FIRING ORDER
(Spark-Ignition or Diesel)

**3-CYLINDER
ENGINES**



1-2-3 FIRING ORDER
OR 1-3-2 FIRING ORDER

**6-CYLINDER
ENGINES**



1-5-3-6-2-4
FIRING ORDER

FOR ALL SPARK-IGNITION
OR DIESEL ENGINES

**V-8
ENGINES**

1-8-4-3-6-5-7-2
FIRING ORDER

FOR ALL SPARK-IGNITION
OR DIESEL ENGINES



Fig. 33—Exhaust Manifold

If any burned gases are left in the cylinders following the exhaust stroke, the amount of fuel-air mixture which can be taken in on the next intake stroke is limited. This reduces engine power and increases fuel consumption.

The only maintenance required for the exhaust manifold is to keep the attaching bolts tight (check every 500 hours).

MUFFLERS

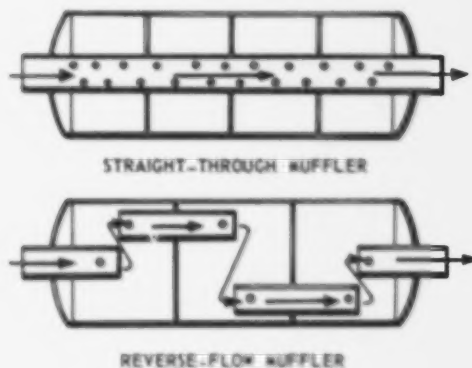
There are two common types of mufflers:

- Straight-through
- Reverse-flow

Let's look at these types.

STRAIGHT-THROUGH mufflers (Fig. 34) consist of a perforated inner pipe enclosed by an outer pipe

Fig. 34—Two Types Of Mufflers



roughly three times larger in diameter. The space between the pipes is sometimes filled with a sound-absorbing and heat-resistant material.

REVERSE-FLOW mufflers (Fig. 33) are hollow chambers using short pieces of pipe and baffles to force the exhaust gases to travel a back-and-forth path before being discharged.

The muffler acts as an expansion chamber, reducing the noise of the spent gases. It also serves as a spark arrester, to reduce fire hazards when operating near combustible material.

Muffler Service

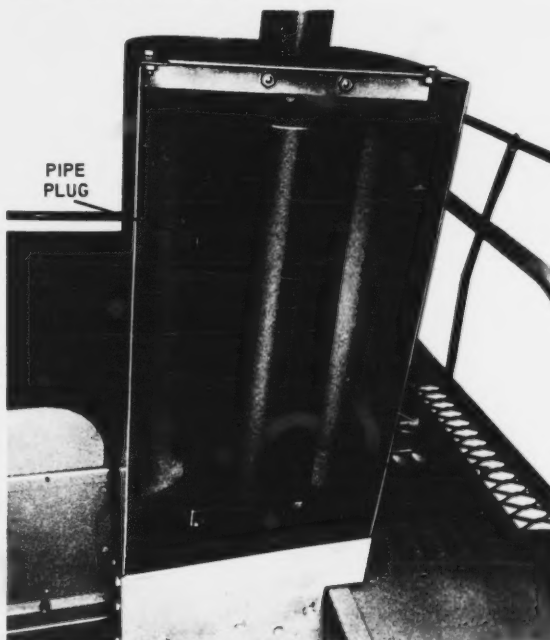
Exhaust systems are designed to provide the least amount of restriction. Excessive restrictions cause back-pressure, resulting in incomplete cylinder scavenging. This, in turn, causes loss of power and increased fuel consumption.

It has been estimated that each 2 psi (14 kPa) of back pressure causes a loss of about four engine horsepower.

CAUTION: One of the products of combustion is carbon monoxide. This is a deadly, odorless, poisonous gas. Ventilate the area anytime the engine is operating.

The complete exhaust system must also be free of leaks. When they do occur, repair them immediately. This is particularly true when the engine is in a machine equipped with a cab or other enclosure.

Fig. 35—Spark-Arresting Muffler



CLEANING SPARK-ARRESTING MUFFLERS

Spark-arresting mufflers should be cleaned every 50 hours of operation. Park the machine in an area where the possibility of fire is not a hazard.

Remove pipe plug from muffler (Fig. 35) to provide an outlet for loosened particles and start the engine. Run the engine from slow to fast idle two or three times to blow out deposits.

Stop engine and replace plug.

WEATHER CAPS FOR MUFFLERS

Some engines have hinged caps on their muffler or exhaust pipe outlets which close when the engine is stopped to protect against rain and weather. This is a good idea, especially for machines parked outside, as rain water can rust the engine valves or damage the turbocharger. Check frequently to see that the cap opens fully when the engine starts and closes tightly when it is shut off.

CRANKCASE VENTILATION

During normal operation, unburned fuel vapor and water vapor are created in the engine. If allowed to condense, these vapors become contaminating liquids that drain into the crankcase. The purpose of the ventilation systems is to circulate fresh air through the engine to carry away these harmful vapors.

As with all ventilating systems, there must be:

- An air inlet
- An air and vapor outlet
- A means of circulating air between the two

The most common types of crankcase ventilation are: oil filler caps, vent tubes, manifold vent, and circulating pump systems.

OIL FILLER CAP VENT

The oil filler cap is probably the most common inlet. A small air cleaner built into the cap filters the air as it is drawn into the system. Some systems use the main air cleaner as the inlet.

CRANKCASE VENT TUBES

The use of a vent tube is one means of circulating the air through the system (Fig. 36). As the machine moves, the air moving past the tube opening creates a lower pressure than that at the breather. Air in the engine naturally flows to this low pressure area, and the tube becomes an outlet for the system. Some vent tubes use a wire mesh screen to filter oil particles out of the vapor.

INTAKE MANIFOLD VENT

On some engines, the intake manifold circulates the air and is also the vent outlet. In this type of ventilation system, a tube connects the crankcase to the intake manifold. The intake vacuum draws the air through the engine, into the manifold, then into the cylinders, and out the exhaust system. A ventilation valve is used to regulate the flow of air into the manifold.

VENT SYSTEM WITH CIRCULATING PUMP

Another type of system uses a vane or impeller pump to circulate the air. The air is taken from the main air cleaner and pumped through the engine. The outlet can be either a vent tube or the intake manifold.

AIR EMISSION CONTROLS

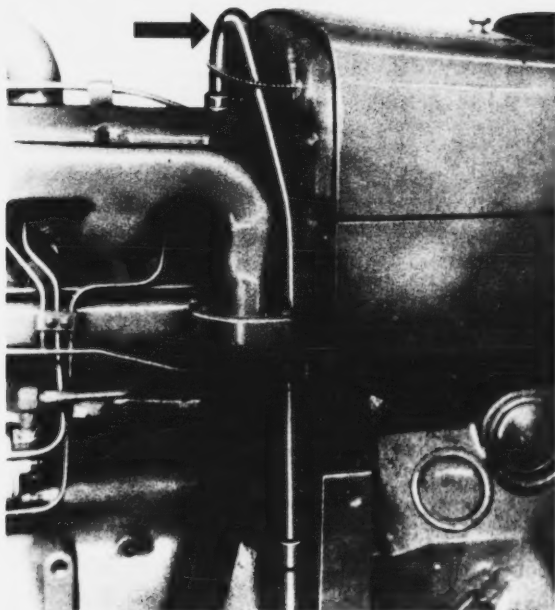
Future developments will probably mean that more agricultural engines will have pollution control devices which route crankcase vapors back to the carburetor or manifold for burning. This will reduce the emission of raw vapors into the atmosphere.

SERVICING THE VENTILATION SYSTEM

Every 50 hours, service the ventilation system. Begin with the inlet. If the oil filler cap is the inlet, clean it with a solvent. If the main air cleaner is the inlet, service it regularly as recommended by the engine manufacturer.

If the system uses a ventilating valve, service it regularly. Some manufacturers recommend cleaning the valve with solvent, while others recommend replacing

Fig. 36—Crankcase Vent Tube



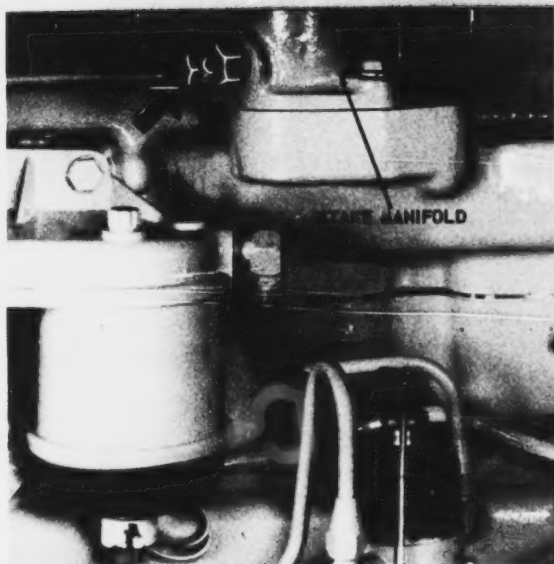


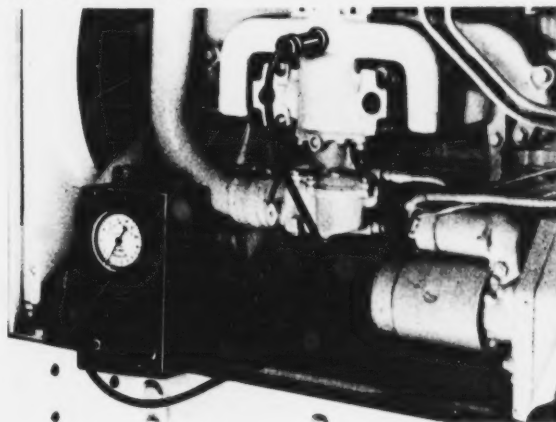
Fig. 37—Manometer or Gauge Connection Point (Diesel Engine)

the valve rather than cleaning it.

If a vent tube is used in the system (Fig. 36), periodically remove and clean it with a solvent. If a filter is used with the vent tube, be sure to clean it, too.

Keeping the engine clean and free of caked-on dirt and oil also helps in crankcase ventilation and general engine cooling.

Fig. 38—Testing Manifold Depression With a Vacuum Gauge (Spark-Ignition Engine)



TESTING AIR INTAKE SYSTEM

When the air flow into the engine is restricted, there is more vacuum or suction in the cylinders. This can cause oil to be drawn in around the valve stems and pistons and so increase oil consumption.

Complete air cleaner service will usually correct the air flow restriction to the engine. However, if a restriction is still suspected, use the tests which follow.

INTAKE VACUUM TEST (DIESEL ENGINES)

Test as follows:

1. Warm up the engine.
2. Connect the gauge to the intake manifold (Fig. 37).
3. Set engine speed at fast idle and note the reading on the gauge. *Too high a reading means that there is a restriction in the air intake system.* Check the engine technical manual for correct specifications.
4. If a restriction is shown by this test, have a serviceman inspect the engine.

MANIFOLD DEPRESSION TEST (SPARK-IGNITION ENGINES)

Use a vacuum gauge calibrated in inches of mercury to perform this test.

1. Connect the vacuum gauge to the intake manifold (Fig. 38).
2. Warm up the engine and operate it at idle speed.
3. Note the reading on the vacuum gauge. Check the engine technical manual for exact specifications.
4. Interpret the gauge reading as given below.

Judging Test Results

- *If the reading is steady and low*, loss of power in all cylinders is indicated. Possible causes are late ignition, bad valve timing or loss of compression at valves or piston rings. A leaky carburetor gasket will also cause a low reading.
- *If the needle fluctuates steadily*, a partial or complete loss of power in one or more cylinders is indicated. This can be due to an ignition defect, or loss of compression due to stuck piston rings or a leaky cylinder head gasket.
- *Intermittent needle fluctuation* indicates occasional loss of power due to an ignition defect or a sticking valve.
- *Slow needle fluctuation* is usually caused by improper carburetor idle mixture adjustment.
- *A gradual drop in the gauge reading* at idle engine speed indicates back pressure in the exhaust system due to a restriction.

Be very careful in analyzing abnormal readings since

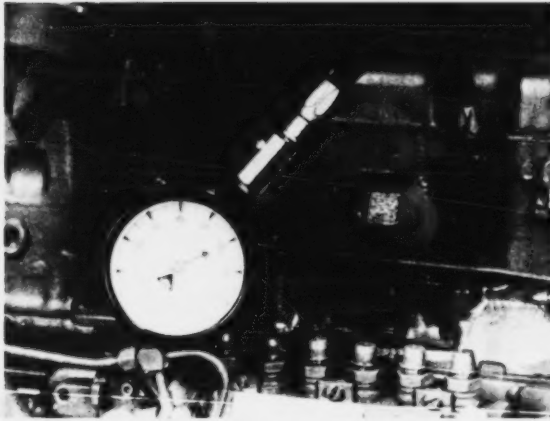


Fig. 39—Checking Engine Compression With A Pressure Gauge

the gauge readings can indicate more than one thing. An air cleaner restriction is the most common cause, but this should be corrected before making the above test. If a problem still exists, have a serviceman inspect the engine.

TESTING ENGINE COMPRESSION

Weak compression results in loss of horsepower and poor engine performance. This is even more true in diesel engines, which depend upon the heat of compression to ignite the fuel in the cylinders.

If you suspect a compression loss, check the engine compression as follows:

1. Warm up the engine to operating temperature and then shut off the engine.
2. Remove the spark plugs or injection nozzles.
3. Connect a pressure gauge to the cylinder port (Fig. 39).
4. On **spark-ignition engines**, be sure that both carburetor throttle and choke valves are in the wide open position. Disconnect the ignition coil-to-distributor wire at the distributor. Ground the wire by placing it in contact with some part of the engine.
5. On **diesel engines**, the air intake system has no throttle valve, so merely be sure that the engine speed control is in the "stop" position.
6. Turn the engine with the starter until the pressure gauge registers no further rise in pressure. It is a good practice to count the number of compression strokes (indicated by movement of the gauge needle) and check each cylinder with the same number of strokes. The engine must be at full cranking speed to get a good reading.
7. Check the pressure reading against the engine technical manual.

8. If the compression is very low, apply oil to the ring area of the piston through the openings. Do not use too much oil to avoid getting oil on the valves. Then check the compression again.

9. Judge the compression readings as given below.

JUDGING COMPRESSION READINGS

All cylinder pressures should be about the same—this is most important. Variations are usually limited to about 10 percent of the full reading.

If compression is too low, the engine must be reconditioned before a tune-up can be effective.

If compression in one cylinder is higher than the others, the other cylinders need reconditioning.

Altitude affects compression pressures. Normally there is about a 4 percent loss for every 1000 feet (300 m) of altitude above sea level. Pressures given are normally for about 1000 feet (300 m) above sea level.

Compression pressures are affected by the **cranking speed** of the engine. Therefore, be sure the batteries are in good condition and fully charged when making a compression test.

If it appears that engine service is needed, take the engine to a qualified serviceman for inspection.

CHAPTER QUIZ

1. Place an I by the parts of the Intake system, an E by the parts of the Exhaust system, an N by the parts that are Not a part of either system, and a B by parts of Both systems.

- | | |
|-----------------------|----------------------|
| a. _____ muffler | d. _____ air cleaner |
| b. _____ gasoline | e. _____ manifold |
| c. _____ turbocharger | f. _____ carburetor |

2. The intake system supplies the engine with clean air of proper (quantity) (temperature) (mixture) (all of these).

3. Which of the following does not apply to dry element air cleaners?

- a. Clean off outside of element with an air hose.
- b. Tap element on a hard surface to remove surface dust.
- c. Wash element in any good detergent.
- d. Use compressed air to dry element.

4. Match the items below:

- | | |
|--------------------------------|--|
| A. Too little valve clearance. | 1. Will cause cracking or breaking of the valve. |
| B. Too much valve clearance | 2. Will cause the valves to burn. |

(Continued on next page)

5. (Fill in blank.) During the_____stroke you can measure the valve clearance.

6. The valve clearance for intake and exhaust valves would need to be checked in the operator's manual since they may be different.

True_____ False_____

7. Air cleaners may contain oil.

True_____ False_____

8. What is the firing order for a 4-cylinder engine?

9. (Fill in blank.) If you identified the end of the compression stroke on an engine you would say the cylinder is at_____.

10. (Fill in blanks.) What are the two types of mufflers?_____and_____.

3

Engine Fuel Systems



INTRODUCTION

Dirt and water are the major enemies of the engine fuel system.

However, today's engines need quality fuels and these fuels will remain reasonably clean if handled properly.

In addition, good maintenance will help keep the fuel system free of dirt and water and will guarantee longer life and smoother operation.

HOW ENGINES USE FUELS

Gasoline, diesel and LP-Gas engines require fuels with certain qualities. This is because of the difference in the way the fuel is ignited in each type.

If you're not familiar with the major types of engines and how they use fuels, study Figs. 2 and 3. They show the operating principles of spark-ignition (carburetor) and diesel engines.

In the **FOUR-STROKE CYCLE** engine (Fig. 2), there are four strokes of the piston, two up and two down, during each cycle. Then it starts over again on another cycle of the same four strokes. This cycle occurs during two revolutions of the crankshaft. Most engines today operate on the four-stroke cycle.

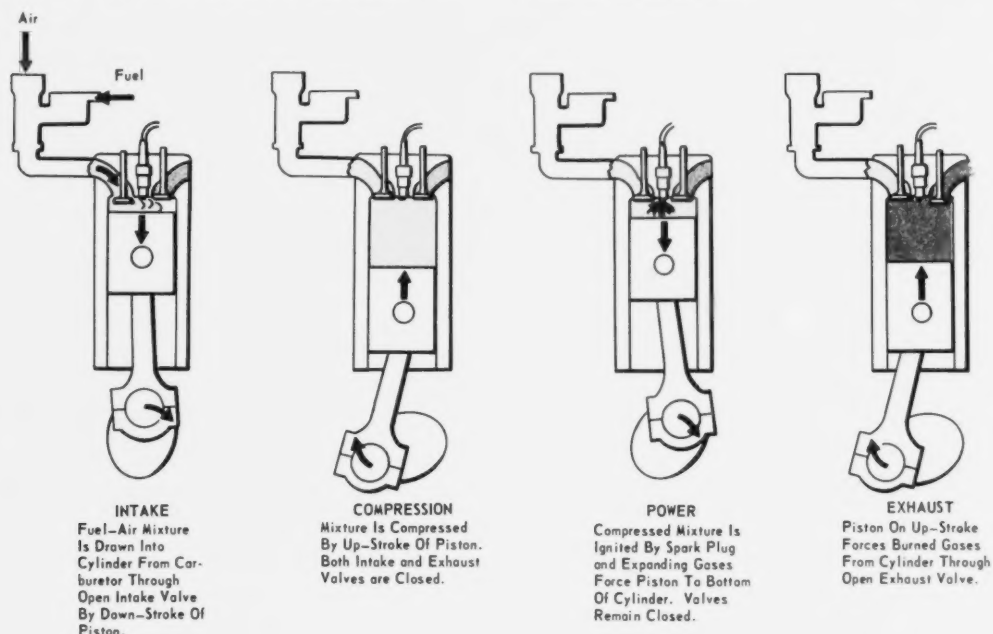
Gasoline and diesel engines ignite their fuel in different ways as shown in Fig. 3.



Fig. 1—Modern Engines Require Quality Fuels From A Clean Source

In **gasoline engines**, fuel and air are mixed *outside* the cylinders, in the carburetor and manifold. The mixture is forced in due to the partial vacuum of the pistons' intake stroke.

Fig. 2—How A Four-Stroke Cycle Gasoline Engine Works



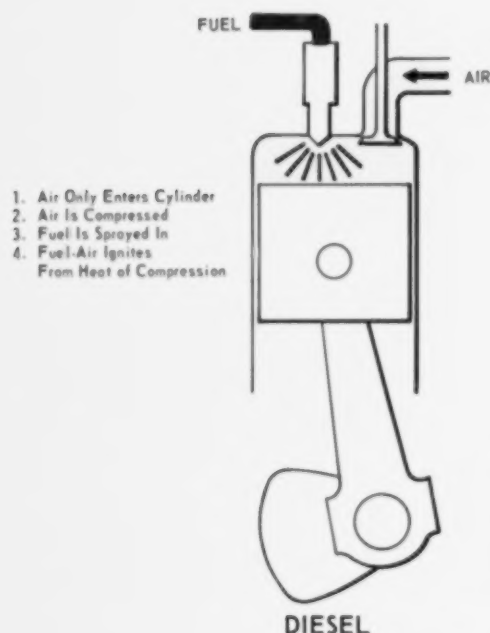
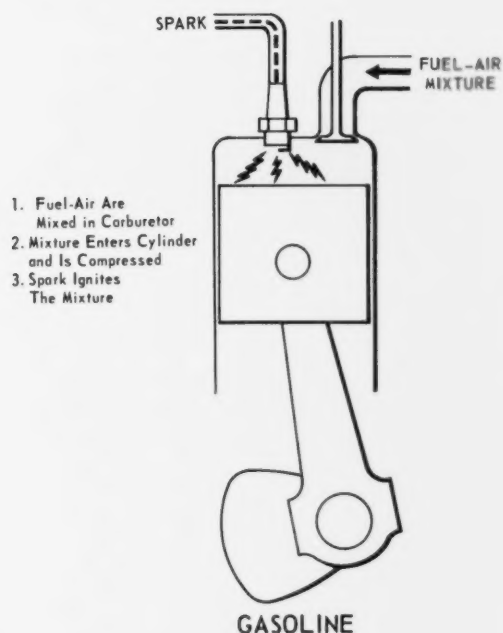


Fig. 3—Spark-Ignition (Gasoline) And Diesel Engines Compared

In *diesel engines*, there is no premixing of air and fuel outside the cylinders. Air only is drawn through the intake manifold and compressed in the cylinders. Fuel is then sprayed into the cylinder and mixed with air as the piston nears the top of its compression stroke.

Gasoline engines use an electric spark to ignite the fuel-air mixture, while diesels use the heat of the compressed air for ignition.

COMPRESSION AND FUELS

Compression ratio is the total volume inside the engine cylinder when the piston is at the bottom of its stroke, compared to the volume when the piston is at the top—closest to the cylinder head (Fig. 4). Note that a common compression ratio for gasoline engines is 8-1, while a 16-1 ratio is common for diesels.

Each fuel has limits on how much it can be compressed and still burn properly. *The fuel required for each type of engine is governed by the compression ratio of the engine.* Fuel is formulated according to the design of the engine in which it is to be used.

The table at right gives the compression ratios and octane ratings expected with modern fuels. The cetane number or ratings of diesel fuels are a measure of the fuel's ignition value and are a prime factor in fuel-engine performance.

COMPRESSION RATIOS AND OCTANE RATINGS OF SPARK-IGNITION FUELS

Fuel	Engine Compression Ratio (approx).	Approx. Octane No.
Kerosene, No. 1 fuel oil*	4.0 to 1	0- 30 (Motor Method)
"Farm Tractor Fuel"***	4.7 to 1	45- 70 (Motor Method)
Gasoline (low grade)	5.0- 6.0 to 1	70- 75 (Research Method)
Gasoline (regular)	7.0- 8.5 to 1	88- 94 (Research Method)
Gasoline (premium)***	9.0-10.0 to 1	About 100 (Research Method)
LP-Gas: Butane	7.8 to 1	95-100 (Research Method)
Propane	8.75 to 1	110-115 (Research Method)

*Well adapted to magneto ignition because of longer spark duration.

**Standard name used in place of a number of other terms such as: distillate or power fuel.

***Not normally used in farm and industrial machines.

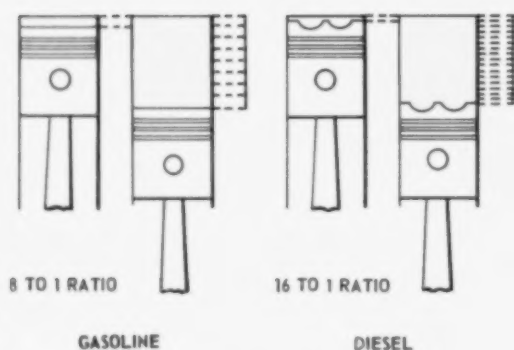


Fig. 4—Compression Ratios Compared For Gasoline And Diesel Engines

SELECTING FUELS

The selection of fuel for your engine will affect the maintenance required and the performance you can expect. By choosing quality fuels you can be assured that you will get the proper octane or cetane rating plus beneficial additives and clean fuel.

SELECTING FUEL FOR GASOLINE ENGINES

Your assurance of getting a fuel with an adequate anti-knock quality is indicated by its **octane** number rating. The operator's manual tells you what the minimum octane rating should be for your engine. Compare it with the octane rating of the fuel supplied by your dealer.

Fuels with the least tendency to knock have higher octane numbers. The names "premium," "regular,"

Fig. 5—Use Only A Good Grade Of Gasoline



JOHN DEERE

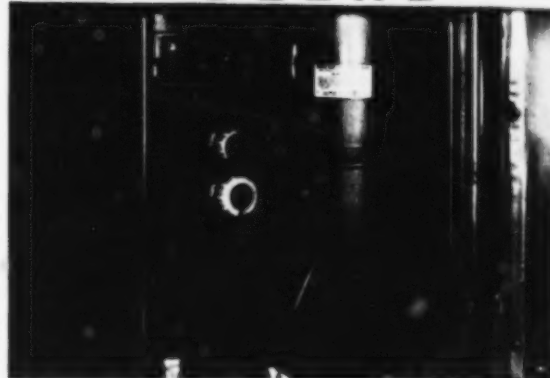


Fig. 6—LP-Gas Engines Have High-Pressure Fuel Tanks

and "low-grade" are rough comparative measures of octane ratings. Most farm and industrial machines use regular grade—88 to 94 octane. If your operator's manual recommends an octane number within the regular range, don't use low-grade (70 to 75 octane) fuel. You can use premium-grade gasoline, but there is usually no advantage because most machine engines are not designed (lack the compression ratio) to secure the benefits of the higher octane rating.

Additives have become essential ingredients of modern gasolines. They are used to raise octane number and to combat surface ignition (anti-knock), spark plug fouling, gum formation, rust, carburetor icing, deposits in the intake system, and intake valve sticking.

Gasohol, a mixture of 90 percent unleaded gasoline and 10 percent ethanol (grain alcohol), is available in many areas as a substitute for gasoline. Gasohol burns cleaner and may provide better mileage in motor vehicles compared to straight gasoline. However, some engine manufacturers have not approved of the use of gasohol in certain engines. So, always be sure the fuel is compatible before using it in an engine or the warranty may be voided. Also, in engines used infrequently, water may combine with the alcohol and cause serious corrosion or damage to some engine components.

IMPORTANT: *Never use non-leaded gasolines unless your operator's manual specifies they can be used in your machine engine. Non-leaded fuel can damage some agricultural engines.*

SELECTING FUEL FOR LP-GAS ENGINES

LP-Gas is short for "liquefied-petroleum gas." It is sometimes indicated as "LPG."

Most LP-Gas used in engines today is all propane or a mixture of mostly propane with some butane.

LP-Gases must be stored and handled in high-pressure containers to keep them in liquid form (Fig. 6). Butane boils at approximately $+33^{\circ}\text{F}$ (1°C), while propane boils at -44°F (-42°C). When confined to a closed container, the pressure varies with the outside temperature. Butane develops pressure of 37 psi (255 kPa) at 100°F (38°C), while propane develops pressure of 195 psi (1350 kPa) at the same temperature.

An LP-Gas engine is similar to a gasoline engine, but the LP-Gas engine is designed with a higher compression ratio—about 7.8:1 to as high as 10:1. Also,

LP-Gases have a high octane rating ranging from about 95 for butane to as high as 125 for propane.

There is very little that can be done about selecting LP-Gas fuel except to deal with a reliable distributor. You are entirely dependent on him to supply fuels that are relatively free of sulfur compounds and other contaminants which may cause difficulties such as filter plugging, valve failures, etc. For cold weather operation, your dealer should give you a different blend (more propane) than for warm weather.

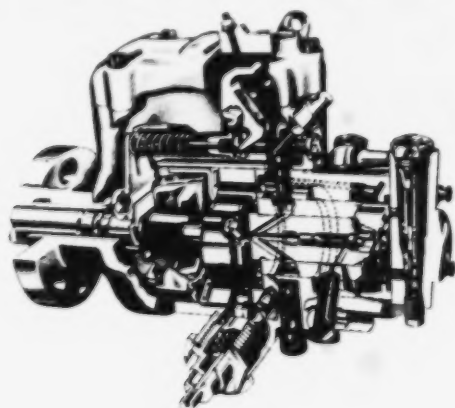
SELECTING FUEL FOR DIESEL ENGINES

You may have heard a saying, "Diesel engines will burn anything." It is true that they will burn a wide variety of fuels; in fact, powdered coal was the first fuel used for diesel engines.

From this you may gain the wrong impression—that selecting fuel for your diesel engine is simply supplying anything it will burn; but diesel fuel selection is far more critical than this.

Knowing how a diesel engine works will help you to understand why certain grades of fuel must be used in them. The operating principles for a 4-stroke cycle diesel engine as compared to a gasoline engine are shown in Fig. 3.

Fig. 7—Precision Diesel Components Require Clean Fuel



Note that there is no spark plug to start the diesel fuel burning. Instead, the air is compressed until it is so hot that fuel injected into it will start burning spontaneously.

The compression ratios for diesel engines are much higher than for spark-ignition engines. This extra compression of the air provides enough heat (900° to 1200°F ; 480° to 650°C) so that the fuel is ignited by heat alone when sprayed into the cylinder. Note in Fig. 5 that the compression ratio for a diesel engine is 16:1. This compares with the compression ratios of about 8:1 in gasoline engines.

The average compression ratio for diesel tractors is approximately 16.3:1. The ratios vary from as low as 14:1 to as high as 20:1.

Diesel Fuel Grades

The two major grades of diesel fuels are:

- No. 1-D Diesel Fuel
- No. 2-D Diesel Fuel

Both fuels (or "fuel oils") are used in high-speed diesel engines on the farm or ranch. Their differences are explained below.

GRADE NO. 1-D FUEL

Grade No. 1-D is a higher class of *volatile* fuel oils from kerosene to the intermediate distillates. These fuels are for use in high-speed engines with variable loads and speeds, and also for extremely cold weather operation.

GRADE NO. 2-D FUEL

Grade No. 2-D is the class of distillate gas oils of *lower volatility*. These fuels are for use in high-speed engines with relatively high loads and more uniform speeds, or in engines not requiring fuels having the higher volatility or other properties specified for Grade No. 1-D.

Remember that engine design and operation materially affect the grade of fuel best suited for an engine.

RECOMMENDED DIESEL FUEL GRADES FOR AGRICULTURAL MACHINES

Below is a typical recommendation from a diesel tractor operator's manual.

Type of Engine Service	Surrounding Air Temperature	Diesel Fuel Grade No.
Light load, low speed, considerable idling.	Above 80°F (25°C)	2-D
	Below 80°F (25°C)	1-D
Intermediate and heavy load, high speed, minimum of idling.	Above 40°F (5°C)	2-D
	Below 40°F (5°C)	1-D
At altitudes above 5,000 feet.	All	1-D

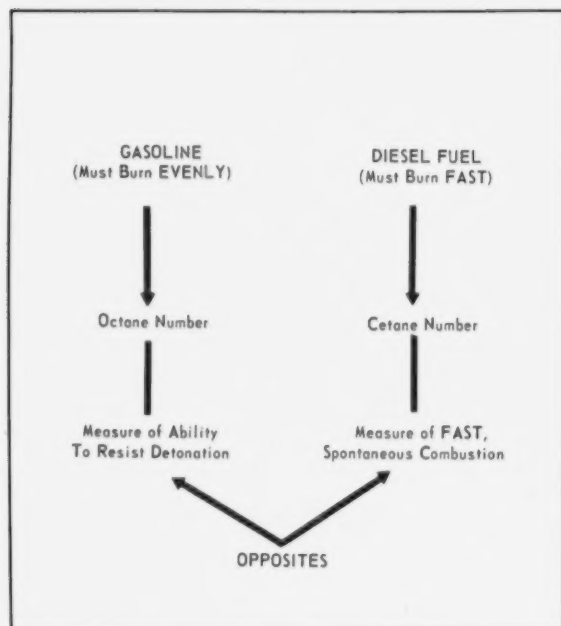


Fig. 8—Octane And Cetane Numbers Are Opposite

Cetane Number

The method of determining the ignition quality of diesel fuel is similar to that used for determining the anti-knock quality of gasoline. However, for diesel fuels this is called **cetane number** instead of octane. These qualities are opposites as shown in Fig. 8.

In general, *high-cetane* fuels permit an engine to be started at lower air temperatures, provide faster engine warm-up without misfiring, reduce varnish and carbon deposits, and help eliminate engine knock.

However, *too-high cetane* numbers may lead to incomplete combustion and exhaust smoke if the ignition delay period is too short to allow proper mixing of the fuel and air within the combustion space.

RECOMMENDED CETANES FOR DIESEL FUELS

Diesel fuels marketed in the United States range from 33 to 64 in cetane number. A typical high-speed engine on a farm tractor or combine calls for diesel fuel with a cetane of "40 minimum." However, higher cetane fuels are specified for some cold weather or high altitude operations.

Knock In Diesel Engines

In **diesel engines**, knock is due to the fuel igniting **TOO SLOWLY** (Fig. 9). It should start to burn almost as soon as it is injected (A). If there is much delay, a fuel build-up results which burns with explosive force (B) and causes knocking.

By contrast, in **spark-ignition engines**, where the fuel-

air charge is mixed and then compressed before ignition takes place, knock is caused by the fuel burning **TOO RAPIDLY**.

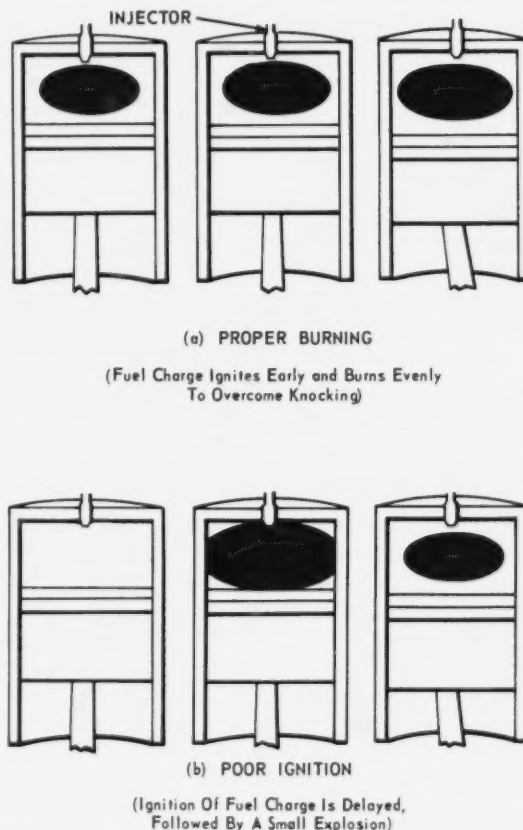
Good diesel fuel provides for early spontaneous burning. By contrast, good gasoline fuels avoid this spontaneous action.

The difference between octane numbers (gasoline) and cetane numbers (diesel fuel) are shown in Fig. 8.

Diesel Fuel Compared With Furnace Fuel

The question is often asked, "*Are diesel fuel and furnace fuel the same?*" It is possible for your fuel supplier to have one fuel that he supplies for both diesel-engine use and heating purposes. Where there is one dominant use, such as home heating compared to limited diesel fuel use, the dealer may not be justified in stocking a separate diesel fuel. So he purchases fuel from his supplier to meet the specifications for both fuels. The refiner can meet this demand because the specifications for both fuels are broad enough that they overlap.

Fig. 9—In Diesel Engines Knock Is Due To Fuel Igniting Too Slowly



If a dealer is supplying big quantities of fuel for both heating and diesel engines, he will normally stock two fuels. In this case the furnace oils usually contain more of the heavy cracked distillates which are quite satisfactory for furnaces, *but are not suitable for diesel engines* (especially with light intermittent loads) and do not generally meet standards.

FUEL AND COLD WEATHER STARTING

The higher the cetane number, the easier your engine will start on diesel fuel. However, in very cold weather, some diesel engines need a starting aid such as ether, which has a cetane rating of 85 to 96 and is highly volatile (Fig. 10).

IMPORTANT: *Spray ether into the engine **only** while cranking with the starter. Ether is highly explosive and can damage the engine if too much is sprayed in before cranking. Never use ether in a diesel engine equipped with glow plugs.*

STORING FUELS

The importance of proper fuel storage cannot be stressed too highly. Many engine difficulties can be traced to dirty fuel and fuel that has been in storage too long.

To keep the fuel system in its most efficient condition, keep all dirt, scale, water, and other foreign matter out of the fuel, and avoid storing fuel for a long period of time.

Fuel should be stored in a convenient place outside of buildings.

Each state has its own laws regarding the handling, storage and use of fuels. It is important that you become acquainted with and obey fuel handling regulations for your own safety and for insurance purposes.

Proper storing and handling of fuels can affect your

Fig. 10—Starting A Diesel Engine In Cold Weather Using Ether Starting Fluid



Fig. 11—Refuel The Machine At The End Of Each Day

safety, how easily your machine starts, and how much maintenance your fuel system requires.

A complete discussion of the storage and safe handling of fuels is given in the John Deere Fundamentals of Service (FOS) manual on "Fuels, Lubricants, and Coolants."

SULFUR IN FUEL

Sulfur in fuel will combine with water and form harmful sulfuric acid in engines. You must remove the acid. Changing oil more often is the best way. Avoiding high sulfur fuel, as much as you can, helps too.

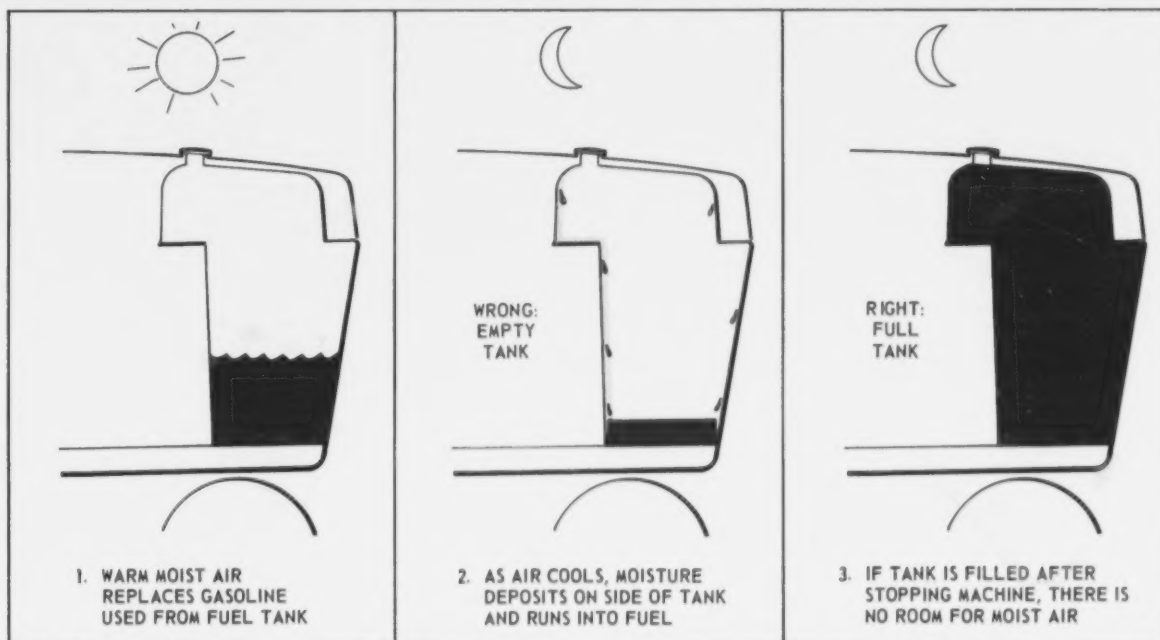


Fig. 12—Why Fuel Tanks Should Be Filled At The End Of Each Day

REFUELING MACHINES

Proper refueling of your machine is more than just filling the tank with fuel. The time and method of refueling are important because of their influence on:

- Keeping out moisture
- Keeping out dirt
- Avoiding fire hazards.

Most operator's manuals suggest that you *fill the fuel tank at the end of the day or whenever you finish using the machine*. This keeps moisture from accumulating in the tank.

Most water in fuel comes from moisture condensing inside the fuel tank. This is true of all fuels except LP-Gas.

Here is why: As fuel is used, air is drawn in. Much of the time the air contains considerable moisture. The warmer the air the more moisture it can hold. At the end of the day, the fuel tank is full of warm moist air which, when cooled at night, deposits moisture on the sides of the tank. As it collects, it runs into and under whatever fuel is left in the tank. (No air enters an LP-Gas tank.) This is shown in Fig. 12.

Water doesn't do much damage to the tank. Most tanks have a protective coating that helps prevent rust. But in a *spark-ignition engine*, any moisture that gets past the sediment bowl in the feed line from the tank, moves into the fuel pump (if the machine has

one) and then into the carburetor. Any sulfur present in the fuel combines with water and attacks the metal parts. In cold weather, water that has collected in the sediment bowl or fuel line may freeze and cause starting trouble.

Diesel fuel and water mix rather readily and the water is slow to settle out—much slower than with gasoline. Yet if water gets to the injection pump, it causes galling and sticking of the finely-machined pump parts. Next is an expensive repair job.

By filling the tank immediately after the machine is used, there is a period of several hours during the night that allows time for most of the water already in the fuel to collect at the bottom of the tank. This is why it is recommended that water be drained from the sediment bowl before starting the engine each day.

Dirt is an equally bad actor in a carburetor. It often closes or partly closes the small openings (orifices) that allow the right amount of fuel to mix with incoming air. In *diesel engines*, it speeds the wear of the close-fitting plungers in the injector pump.

Fire hazards exist when handling any kind of fuel. But with gasoline and LP-Gas the risk is somewhat greater. There are two reasons:

(1) Either fuel vaporizes at temperatures around zero. Only a small amount mixed with air (6 percent or less of gasoline vapor) will explode if exposed to a spark or flame.

(2) Since the vapors are heavier than air, they settle to a low spot and remain there unless ventilated out.

Kerosene and fuel oil don't vaporize readily until the

temperature reaches 110°F (45°C) or more. This makes them less of a hazard than gasoline, unless you spill them on a hot manifold or other hot surfaces. Then they vaporize readily. With so much vapor present, a spark or flame will readily ignite it.

Consequently, if your machine is hot and you haven't time to wait 4 or 5 minutes for it to cool, wait and re-fuel the next morning. The risk of water in your fuel tank becomes less important than the risk of fire or explosion from refueling a hot engine.

Refueling of machines is discussed as follows:

- Refueling with liquid fuels
- Refueling with LP-Gas

We will now explain each one.

REFUELING WITH LIQUID FUELS

When filling a fuel tank with *gasoline, kerosene or diesel fuel*:

1. Check against fire hazards.

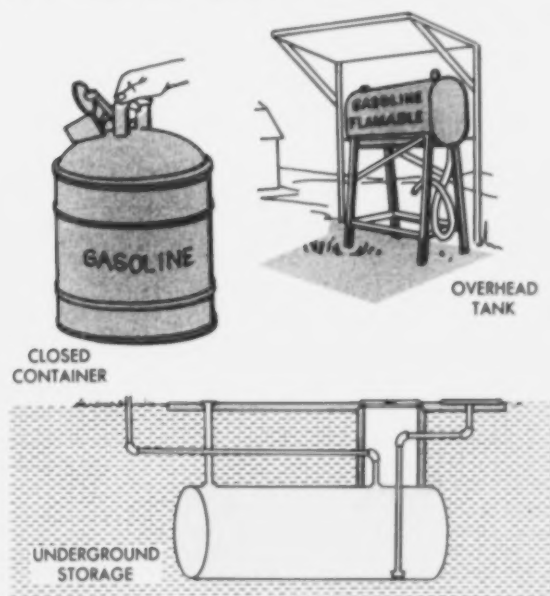
Shut off engine and turn off all electrical switches to lessen the danger of a spark.

Allow engine to cool if extra hot. Be sure there are no open flames and that no one is smoking.

2. Check mouth of container or hose nozzle for dirt. Remove any dirt with a clean cloth.

Be sure to use closed containers if you are hauling fuel to the field (Fig. 13). There is less chance of dirt and moisture entering the fuel tank if you fill your

Fig. 13—Fuel In Storage Containers



machine directly from an overhead supply tank or pump (Fig. 13).

Use only authorized gasoline containers; these are painted red. Paint your kerosene, distillate or diesel fuel containers green.

3. Remove dust and loose dirt from fuel tank cap and area around tank opening.

4. Fill fuel tank almost full.

Leave space in neck of opening for fuel to expand if heated; this helps avoid overflow and possibility of fire.

If filling from fuel drums, don't move them around so as to agitate the fuel and cause water and dirt to mix with it.

With diesel fuel, leave 3 or 4 inches of fuel in the bottom of the storage tank as a safeguard against moisture and dirt.

If your *fuel supply is low* in the supply tank, you run a risk of drawing off both dirt and water into your fuel tank. Rather than take this risk, line a clean funnel with a chamois and filter the fuel through it. The chamois removes both dirt and water.

Let fuel stand at least 10 hours after supply tank is filled before fueling machines to permit any dirt in the fuel to settle out.

5. Replace fuel tank cap tightly.

Make it a practice to check the opening in the fuel tank cap occasionally. If it becomes clogged, a vacuum tends to develop in the fuel tank and fuel won't feed into the carburetor satisfactorily.

CAUTION: Never smoke while filling a fuel tank.

REFUELING WITH LP-GAS

As we discussed earlier, LP-Gas is a petroleum gas commonly made up of propane and butane (some is all propane). At ordinary temperatures it changes to a gas, and in order to keep it in liquid form it must be kept under pressure. For this reason, the method of filling the machine fuel tank is different than with other fuels.

Note in Fig. 14 there are two hose lines extending from the storage tank to the machine fuel tank.

The reason for the two lines is shown in Fig. 14. One line delivers liquid fuel from the supply tank to the machine tank, while the second line allows vapor to flow from the machine tank back to the supply tank. In this way no air enters either tank and there is no loss of pressure due to escaping gas vapor.

CAUTION: Don't ever attempt to fill the tank without a vapor-return hose line. While it is true that it can be done by allowing vapor to escape to open air, this practice violates all safety regulations. It is extremely dangerous and fire or explosion is almost certain if continued over a period of time.

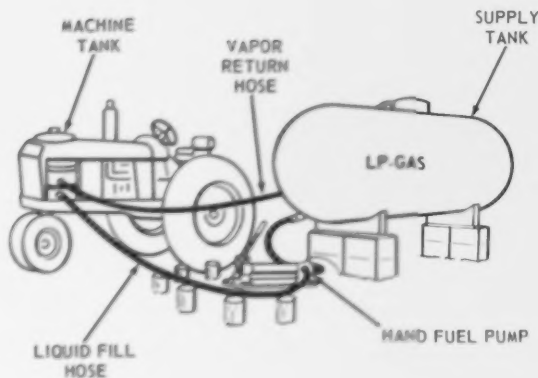


Fig. 14—Refueling With LP-Gas

As long as the level of the liquid in the supply tank is above the level of the liquid in the machine tank, it will flow by gravity from the storage to the machine tank. If the storage tank is lower than the machine tank, a hand-operated or motor-operated pump is used to pump the liquid from the supply tank (Fig. 14).

IMPORTANT: A different set of valves is used for filling the fuel tank from those used when operating the machine. Check your operator's manual for details on fueling your type of machine. In general, the procedures are as follows:

1. Check to make sure engine is turned off and that there is no smoking or flames nearby.

These precautions are extremely important. It is difficult to know when you have an LP-Gas leak. The gas is invisible and the odor is not as easy to detect as with gasoline. In other respects, it has about the same hazards as when filling a gasoline tank.

Never attempt to fuel your machine inside a building or over a pit. There is too much danger of gas pocketing and providing conditions for an explosion.

2. Remove dust caps (covers) from machine fuel-tank connections and hose ends.

Valves inside the tank keep liquid and gas from escaping.

The vapor return valve is built somewhat differently from the filler valve. It has one check valve and an excess-flow valve on the end. The excess-flow valve closes in case there is a rapid movement of gas from the tank such as might happen if a hose should break.

3. Attach vapor-return line to vapor-return connection on machine and open hand valve (Fig. 15).

When this valve is opened, pressure is equalized between the storage tank and tractor tank. This is necessary for the liquid to flow into the tractor tank.

4. Attach liquid-fill hose to connection on machine

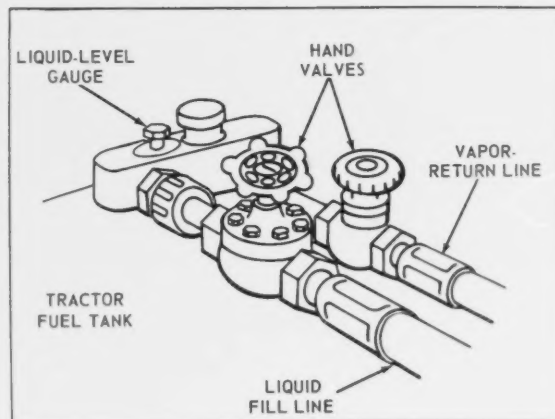


Fig. 15—Hand-Operated Valves On Hoses Which Connect To Machine Tank

tank and open valve (Fig. 15).

5. Operate pump if storage tank is below level of machine.
6. Watch fuel gauge to determine when tank is 75 percent full.

This step is important in order to keep from overfilling the fuel tank.

Your gauge may be of the *float type*; if so, it shows the percentage of liquid fill in your tank at all times.

Some gauges are of the *tube type*. To determine percentage of fill with this type of gauge, level of liquid is checked by rotating tube inside tank. It is connected to a dial handle on the gauge.

7. Check fuel overflow valve until liquid appears.

Open this valve momentarily, then close until liquid appears. This shows when liquid has reached proper level in tank. Don't leave this valve open during the filling process. As discussed earlier, this is extremely dangerous and violates all codes and laws regarding proper and safe filling of LP-Gas tanks.

8. Close both line valves and disconnect from machine tank.

The machine fuel tank is now around 80 to 85 percent full. This still leaves room for vapor at the top and provides for expansion of the fuel in case of heat.

9. Replace dust caps.

A safety-relief valve is mounted on your tank to relieve pressure in case you overfill and the pressure gets too high for safety.

CAUTION: When the hoses are disconnected from the machine tank, a small amount of liquid fuel is lost. Continue to avoid smoking or lighting a match until the fuel has had time to vaporize and be ventilated away from the machine.

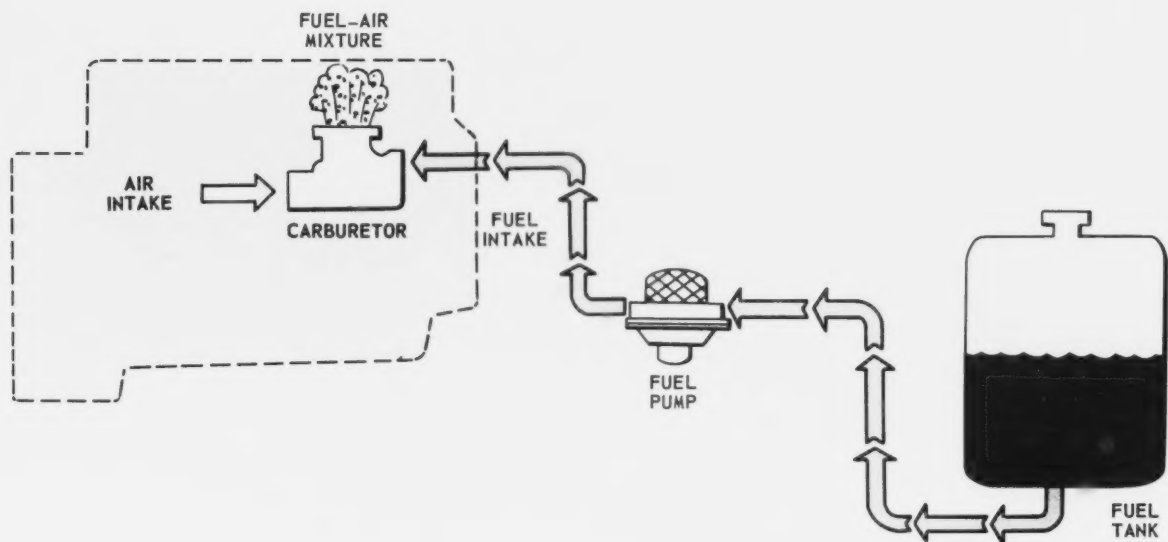


Fig. 16—Gasoline Fuel System

GASOLINE FUEL SYSTEMS

INTRODUCTION

The gasoline fuel system supplies a combustible mixture of fuel and air to power the engine.

The gasoline fuel system (Fig. 16) has three basic parts:

- Fuel Tank
- Fuel Pump
- Carburetor

The FUEL TANK stores the gasoline for the engine.

The FUEL PUMP moves fuel from tank to carburetor.

A fuel pump is needed only with force-feed supply systems. When fuel tank is above the engine, gravity moves fuel to the carburetor.

The CARBURETOR does two jobs: (1) atomizes fuel for the engine, and (2) provides proper fuel-air ratio.

Most systems also have a fuel sediment bowl and strainer below the tank outlet, or it may be part of the fuel pump.

OPERATION

How do these parts work together as a team?

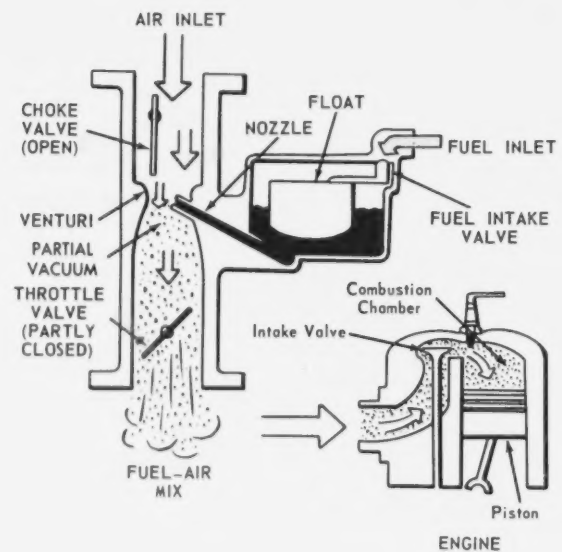


Fig. 17—Basic Carburetor At Part Throttle Or Low Power

Operation of the basic system is shown in Fig. 16.

The *fuel pump* draws fuel through a line from the tank and forces it to the *float chamber* of the carburetor, where it is stopped.

The *carburetor* is basically an air tube which operates by a change in air pressure.

Filtered air flows in at one end and fuel-air-mixture is drawn out at the other end (Fig. 17).

The pressure change is created when air flows through the narrow neck, or venturi, because air moves faster through a restriction. This lowers the air pressure beyond the restriction.

As low-pressure air rushes by the nozzle which projects into the venturi, small drops of fuel are drawn out and mixed with the air.

At the same time, the engine's intake stroke creates a partial vacuum which draws the fuel-air mixture into the combustion chamber of the cylinder as shown in Fig. 17.

The fuel-air mixture must pass the *throttle valve* which opens or closes to let the right volume of fuel-air into the engine. This is controlled as the operator sets the engine speed or by the governor's action.

The *choke valve* also controls the supply of fuel to the engine. When starting the engine in cold weather, for example, it can be partly closed, forming a greater vacuum. This vacuum causes more fuel and less air to be drawn into the combustion chambers. The richer mixture burns easier, providing extra power in the cylinders for the harder job of starting.

The operation of the carburetor at part throttle or low power is shown in Fig. 17; operation at full throttle or full power is shown in Fig. 18.

The chart below gives a summary of the various carburetor systems.

OPERATION OF CARBURETOR SYSTEMS

System	Function
1. Float . . .	Controls flow of fuel from tank to carburetor for a constant level of fuel in carburetor.
2. Choke . .	Creates a rich fuel mixture for starting a cold engine.
3. Throttle .	Allows engine to accelerate smoothly from idle to high speeds.
4. Load . . .	Allows engine to operate at its maximum power output.
5. Idle . . .	Allows engine to operate economically at idle speeds when power is not needed.

IMPORTANCE OF SERVICE

When the fuel system is operating properly, the maximum in fuel economy and horsepower is achieved.

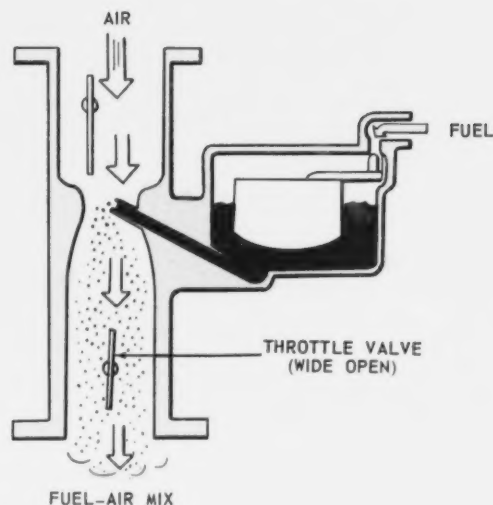


Fig. 18—Basic Carburetor At Full Throttle Or Full Power

If too rich a mixture is used, fuel consumption may be increased by 10 percent or more. A too-rich mixture can also cause carbon deposits to accumulate in combustion chambers.

Too lean a mixture reduces power and may cause valve burning from extra-hot, slow-burning gases.

Always keep the fuel tank and filter clean to prevent dirt, rust or other foreign matter from clogging the carburetor and filters. Moisture in the fuel can cause rust and poor engine operation.

TOOLS AND MATERIALS NEEDED

1. Wrenches (inch or metric, as required).
2. Screwdriver.
3. Container of cleaning solvent (not gasoline).
4. Goggles or glasses for eye protection.

ADJUSTING THE GASOLINE CARBURETOR

Check and make carburetor adjustments every 250 hours of engine operation, or as needed.

Before making any carburetor adjustments, check the following:

1. Remove the strainer screen from the carburetor (if it has one) (Fig. 19) and clean the screen in solvent or replace it if it is dirty. Reassemble screen.

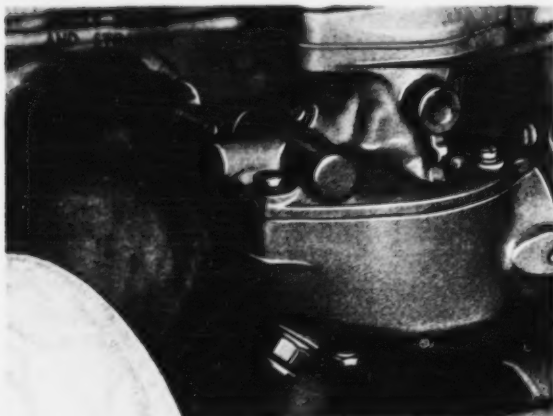


Fig. 19—Carburetor Fuel Strainer

in solvent if it is dirty. Reassemble screen after cleaning.

CAUTION: Gasoline is flammable. To avoid injury, do not smoke or allow any flame near the area. Also do not allow gasoline to spill onto any hot surface, such as a hot manifold.

2. Check for air leaks at manifold connections and carburetor gaskets. With the engine running, squirt a few drops of oil over suspicious areas. If oil is drawn into the manifold, air is leaking into the manifold. Tighten fittings and check again. If leaks persist, replace gaskets.

The carburetor can't be adjusted properly if the screen is clogged or the manifold is leaking.

Adjusting Idling Speed

The idle adjusting screw (Fig. 20) determines how completely the throttle valve closes. This controls the idling speed of the engine.

To adjust the idling speed, proceed as follows:

1. Start the engine and allow it to warm to operating temperature.
2. Set the speed-control lever at the completely closed position.
3. Turn the idle speed adjusting screw clockwise to increase speed, counterclockwise to decrease speed.

Check your operator's manual for proper idling speed and the recommended point for measuring it. Depending on the engine, the speed may vary from 300 to 800 rpm. If the engine has a tachometer, use it. But setting the speed by sound is not a good way because you could be off several hundred rpm. On some engines the idling speed can be measured at the power take-off shaft by using a portable tachometer or speed counter and a watch. An electric tachometer connected to the ignition system can also be used for checking speed.

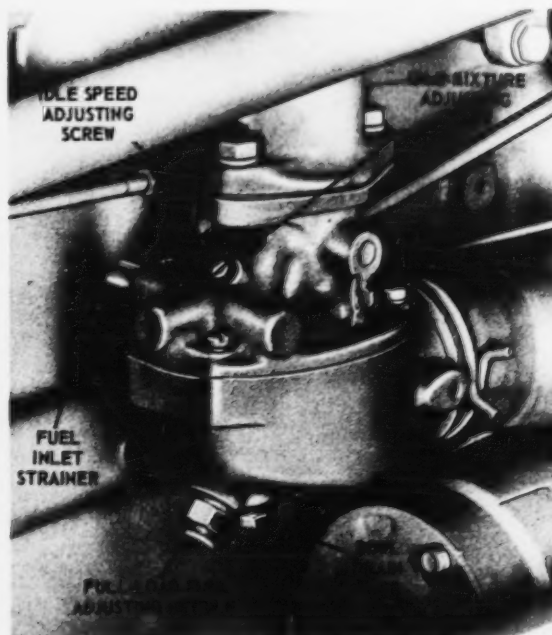


Fig. 20—Adjusting Points On Typical Carburetor

Adjusting Idling Fuel-Air Mixture

The idle-mixture adjusting screw (Fig. 20) adjusts the fuel-air mixture while the engine is idling.

Your operator's manual may indicate a setting of so many turns from the completely closed position. If your carburetor is a little dirty, however, this may not be close enough. Use the following procedures to get a finer adjustment:

1. With the engine at normal operating temperature, set the speed-control lever in the idling position.
2. Turn the idle-mixture adjusting screw (Fig. 20) clockwise slowly until the engine begins to "roll" or shake. This decreases the air flow and causes a richer mixture on some engines and decreases fuel flow on other engines, resulting in a leaner mixture. The engine isn't getting the correct fuel-air mixture when it idles roughly.
3. Turn the adjusting screw counterclockwise until the engine begins to run smoothly. Do this slowly so that the engine has a chance to adjust to the changing mixture. You may have to change the direction you are turning the screw several times until you are certain that the best setting has been achieved. This is when the engine runs the smoothest.

NOTE: Another method is to turn the screw in until the engine runs rough. Then turn the screw out until

the engine again runs rough, counting the number of turns. Now turn the screw in one-half the number of turns for the best setting for smooth operation and economy.

Some two-cylinder engines have an idling screw for each cylinder. To adjust these, short the spark plug on one cylinder while adjusting the idle mixture on the other.

NOTE: If the engine is not affected by one or two complete turns of the adjusting screw, something may be wrong. The float valve in the carburetor may be leaking, the fuel level may be too high, or deposits in the manifold around the throttle valve may be restricting air flow. See your dealer if you can't correct the problem.

4. Recheck the idle speed after the idle fuel is set, as the mixture could change the speed. Generally, idle speed and idle fuel should be set together.

Adjusting Load Fuel-Air Mixture

The valve which controls the fuel for full-load or high-speed conditions is called "main adjusting needle", "power-adjusting needle", or "full-load fuel adjusting needle" (Fig. 20). Many later model engines do not have this adjustment (are preset at factory).

To make this adjustment, the engine must be up to full operating temperature. Adjust the load fuel-air mixture as follows:

1. Run the engine at full throttle and provide a constant load on the engine, if possible. A dynamometer and flow meter is best, but you can make the adjustment without these by trial and error. See Chapter 10 for dynamometer procedures.

If you make the adjustments without load, follow up with a final check to make sure the adjustment is satisfactory under load.

CAUTION: Do not try to adjust the carburetor while your machine is in motion. You may seriously injure yourself and cause an accident which could injure someone else nearby.

2. Turn the full-load adjusting screw clockwise until the engine begins to lose power.

This indicates that you have reached the border line on the lean side of the mixture as shown by (A) in Fig. 21. At this setting, your engine will have high fuel efficiency, but it would not be developing its maximum horsepower. The temperature of the exhaust would be too high also. This could lead to burned valves.

3. Turn the adjusting screw counterclockwise (or out) until the engine gives off black smoke from the exhaust.

This indicates that the fuel-air mixture is too rich as shown by (B) in Fig. 21. You will get satisfactory horsepower, but fuel efficiency will be low.

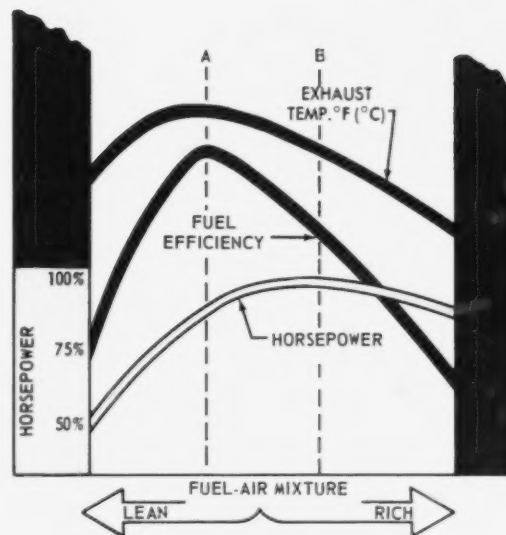


Fig. 21—Relationship Of Exhaust Temperature, Fuel Efficiency And Horsepower To Different Fuel-Air Mixtures

4. Turn the screw clockwise until engine runs smoothly and at full speed. Turn the screw slowly so that the engine will have time to adjust.

NOTE: The same method as shown in "NOTE" under step 3 of idle fuel adjustment can also be used here.

5. Check this adjustment by accelerating the engine quickly while under load.

If you were not able to adjust the engine under load, you should now operate the tractor to determine how it accelerates under load.

The engine should accelerate quickly when you move the speed control lever suddenly. If the engine backfires, the mixture is too lean. If dark-colored smoke comes from the exhaust, the mixture is too rich.

MAINTENANCE TIPS FOR CARBURETORS

Carburetor adjustment is part of maintenance, but repair of the carburetor requires special knowledge and tools. If you do service the carburetor, the tips listed below will help you.

1. Always **service** the carburetor at these times:
 - a. After engine valve grinding or major engine overhaul.

b. Every year or at the beginning of each season on seasonal machines. At this time, clean the carburetor, repack the shaft, check the bearings, and replace the seals and gaskets.

2. Always **adjust** the carburetor at the following times:

- a. During engine tune-up
- b. After major overhaul of the engine
- c. Whenever the carburetor has been removed for service.
- d. Anytime the engine idles badly or requires speed adjustment

3. Repair kits are provided for many carburetors. When repairing, be sure to use **ALL** of the new parts in the kit not just those which **appear** worn.

4. Clean all parts thoroughly when repairing the carburetor. Use a carburetor cleaning solution for removing varnish-like deposits from all metal parts and rinse them in solvent.

5. Never use small wires or drills to clean out jets or orifices. This may enlarge or burr the precision bores and upset the performance of the carburetor.

6. Never use compressed air to clean a completely assembled carburetor. To do so may cause the metal float to collapse.

7. To test a metal float for leaks, immerse it in hot water. If air bubbles escape from the float, replace it. Do not attempt to repair a float unless recommended.

8. Always drain the carburetor before any long storage period. Many carburetors have a drain plug in the fuel bowl.

9. Most carburetors are vented to avoid vapor lock. Be sure the vent is kept clean and open.

10. Never turn adjusting needles too tightly against their seats as you may damage them.

11. Use special tool kits, when available, to recondition the carburetor.

12. Be sure to tighten the screws which hold the throttle disk in place. If loose, suction from the engine may draw screws into the combustion chamber.

13. Always check the height of the float when assembling the carburetor. See the machine technical manual for the correct height. If the float is badly bent or warped, replace it. Use a special float bending tool to adjust the float when recommended.

SERVICING GASOLINE SEDIMENT BOWL AND FUEL STRAINER

Most agricultural machines are equipped with a combination sediment bowl and fuel strainer (Fig. 22).

NOTE: In extremely trashy or dry conditions, some manufacturers recommend replacing glass sediment bowls with metal bowls to reduce possibility of a bowl breaking and causing a fire.

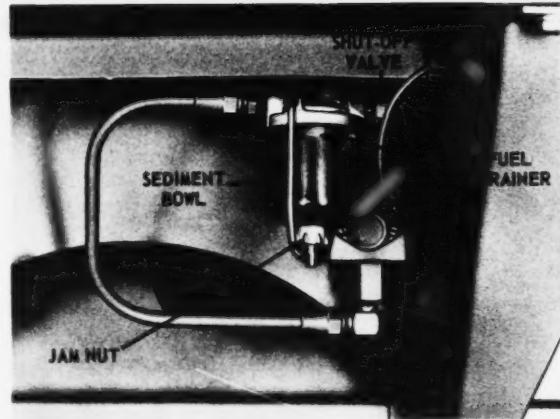


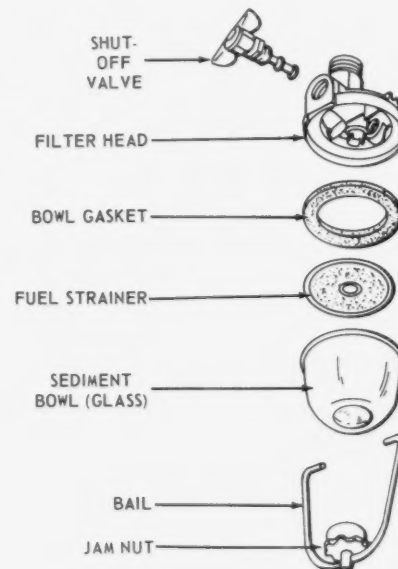
Fig. 22—Gasoline Fuel Sediment Bowl and Strainer

Most sediment bowls should be visually checked every 10 hours for dirt and water deposits. However, actual service intervals vary widely and some manuals say "periodically".

The tools and materials needed to clean these parts are:

1. Container of cleaning solvent (not gasoline)
2. New gaskets (where used)
3. Clean, lint-free rags

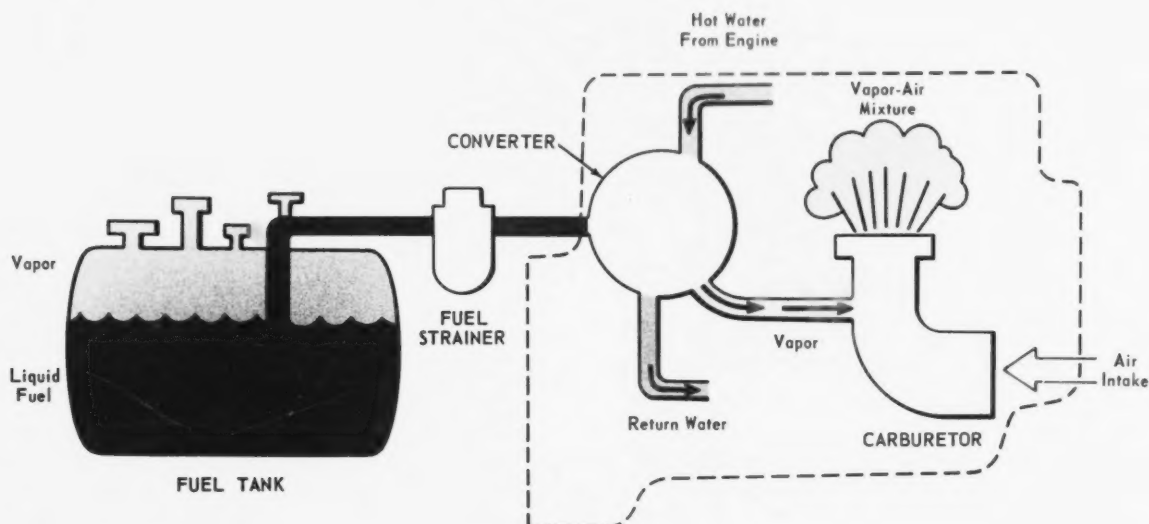
Fig. 23—Servicing Gasoline Fuel Sediment Bowl And Strainer



To clean the sediment bowl and strainer, proceed as follows:

1. Shut off fuel supply line at fuel tank or sediment bowl.
2. Remove sediment bowl gasket and strainer screen (Fig. 23).
3. Wash screen in cleaning solvent. If screen is difficult to clean, remove varnish or gum deposits with a carburetor cleaner solvent.
4. Clean sediment bowl with cloth dampened in cleaning solvent. Wipe bowl dry and remove any lint remaining in bowl.
5. Drain sediment from bottom of fuel tank, or open fuel valve and observe fuel as you catch it in a container. This should remove dirt or water from the tank and fuel line. If the vent hole in the fuel tank cap is plugged, the flow will be slow. Clean the cap, if clogged, in solvent.
6. Reassemble sediment bowl, strainer or filter and gasket (Fig. 23) and tighten the jam nut. (On some systems you must let fuel run into the bowl before tightening it completely.)
7. Open the fuel valve. Start the engine and check for fuel leaks.
8. Reassemble the sediment bowl, strainer or filter and gasket (Fig. 23).
9. Tighten the bowl against gasket. (On some systems you must let fuel run into bowl before tightening it air-tight.)
10. Open the fuel valve. Start the engine and check for leaks.

Fig. 24—LP-Gas Fuel System



LP-GAS FUEL SYSTEMS

LP-Gas vaporizes very easily. In fact, it normally remains a liquid only when under pressure. Therefore, it must be kept in strong tanks.

LP-Gas is vaporized *before* it reaches the carburetor, while gasoline remains a liquid until this point. This is the basic difference between the two systems.

OPERATION

In most systems, the fuel is drawn from the tank as a pressurized *liquid* and then vaporized (Fig. 24).

Vapor is taken from the top of the tank only for starting the engine. This is done because in a cold engine there is not enough heat to convert liquid fuel to vapor. Once the engine is started and warmed up, it can be switched to liquid withdrawal again.

PARTS OF LP-GAS FUEL SYSTEM

The LP-Gas fuel system (Fig. 24) has four basic parts:

- **Pressurized Fuel Tank**
- **Fuel Strainer**
- **Converter**
- **Carburetor**

The **PRESSURIZED FUEL TANK** stores the liquid fuel under pressure. A space for vapor is left at the top of the tank.

The **FUEL STRAINER** cleans the liquid fuel. It normally has a solenoid valve which permits flow only when the engine ignition is turned on.

The **CONVERTER** changes the liquid fuel to vapor by warming it and then lowering the pressure of the vapor.

The **CARBURETOR** mixes the fuel vapor with air in the proper ratio for the engine.

IMPORTANCE OF SERVICE

The LP-Gas fuel system requires maintenance similar to the gasoline system. To achieve the maximum fuel economy and horsepower, you must perform periodic service to keep the system operating correctly.

As with gasoline fuel systems, if the carburetor is not adjusted correctly, fuel consumption can be excessive or power can be lost.

Clean fuel is not a major problem with LP-Gas; however, don't neglect it. Small particles of dirt or gummy residues can lodge in the finely machined valve openings and damage the seats when valves are closed. This can cause dangerous gas leaks or plugging of the lines. Plugging can be detected by frosting of the filter or line at the point of stoppage.

CLEANING THE LP-GAS FUEL STRAINER

Clean the LP-Gas strainer as recommended. Intervals vary from every 100 hours to yearly. However, if the strainer clogs, frost will form on the outside of the metal strainer.

The tools and materials needed to clean the filter are:

1. Set of wrenches (inch or metric, as required).
2. Container of solvent (not gasoline)
3. New gaskets (where used)
4. Clean, lint-free cloths
5. Source of air pressure

To clean the strainer, proceed as follows:

1. Close liquid and vapor valves at fuel tank (see Fig. 25).
2. Remove the drain plug from the strainer (Fig. 25).
3. Open the vapor valve at tank *slowly*. This should blow accumulation of moisture and sediment from the strainer bowl.

CAUTION: Never do this in the vicinity of a flame as a spark or explosion could result. Also, be sure there is plenty of ventilation.

4. Close the vapor valve and reinstall the plug.

This procedure will clean some of the contamination from the strainer bowl, but to clean the filter com-

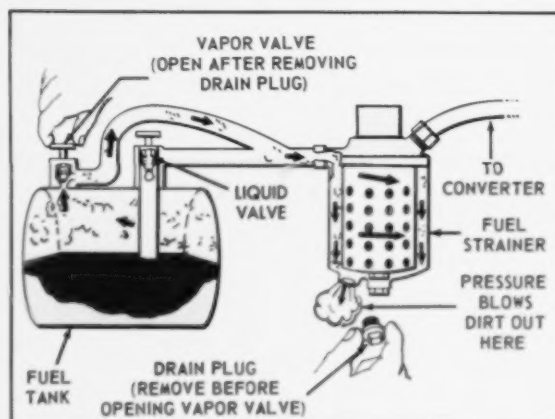


Fig. 25—Cleaning LP-Gas Fuel Strainer

pletely, it must be removed.

For complete cleaning of strainer:

1. Be sure that both the vapor and liquid supply valves are closed.
2. Loosen the drain plug in the bowl slowly so that any pressure build-up can be relieved.
3. Loosen the nut or bolt holding the filter bowl and remove bowl, gasket and filter element.
4. Wash the filter in solvent if the filter is washable. Replace disposable filters with new ones.
5. If a disk-type filter is to be reinstalled, finish drying the filter by blowing air through one end. This forces out any particles from inside the filter element.
6. Clean sediment bowl with a cloth dampened with the cleaning solution. Wipe the bowl dry and be sure no lint remains in the bowl.
7. Install gasket, filter and sediment bowl and tighten nuts or bolts to hold filter in place.
8. Open the fuel supply valves at tank and check for leaks. Brush on a soapy-water solution around connections. If bubbles are present, tighten connections. If tightening does not correct the problem, replace the necessary parts.

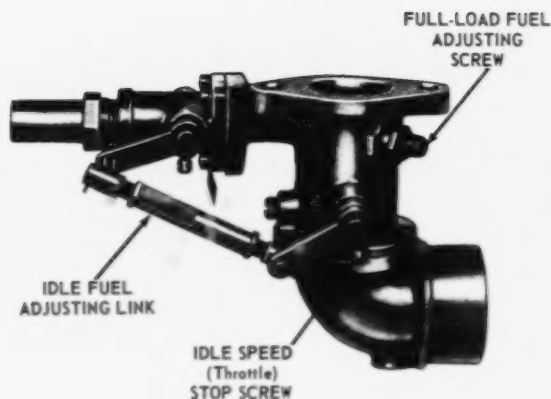


Fig. 26—Adjusting Points On A Typical LP-Gas Carburetor

ADJUSTING THE LP-GAS CARBURETOR

Refer to your operator's manual for specific instructions. Some manufacturers recommend that you take your machine to your local dealer for this service. However, many LP-Gas carburetors can be adjusted as follows:

1. Warm up the engine fully.
2. Adjust the idle speed at the throttle stop screw (Fig. 26). Normally adjust with the throttle disk closed and try to get the slowest engine idling speed without stalling or "roughening." See your operator's manual for recommended idle rpm.
3. Adjust the idle fuel mixture at the adjusting link (Fig. 26). With the engine at slow idle, turn the link until the engine begins to stall. Then turn the link the other way until the engine idles smoothly.
4. If necessary, readjust the idle speed (step 2).
5. Adjust the full-load fuel mixture per the specification. For safety, load the engine but keep the engine stationary (as with a dynamometer). With a tractor you can use the tractor to power a grinder or other PTO driven unit. With self-propelled machines such as cotton pickers or combines, the harvesting mechanism can provide the engine with a load.

IMPORTANT: Never let an LP-Gas engine run with the fuel mixture "too lean." LP-Gas burns hotter than gasoline and will allow the engine to develop maximum horsepower. However, this lean burning will result in burned valves and pistons.

Be sure the throttle is wide open. Turn the full-load fuel adjusting screw until the engine starts to lose power. Then back it out until the engine picks up speed and runs smoothly.

NOTE: This adjustment has no effect unless the engine is at full throttle under load and the throttle disk is wide open.

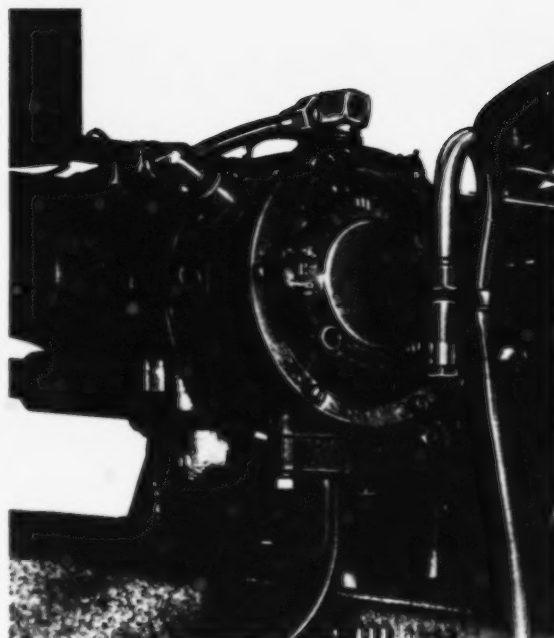


Fig. 27—LP-Gas Converter

SERVICING THE LP-GAS CONVERTER

The converter (Fig. 27) is constructed so that it will seldom cause trouble, providing clean fuel is used in the tank and clean, soft water in the cooling system.

If the converter frosts up when the engine is cold, it is probably due to a leaking high-pressure valve caused by dirt under the valve seat.

If frosting occurs when the engine is hot, it is probably due to poor coolant circulation through the heat exchanger—or a restriction in the high-pressure valve.

To check the converter for leaks, turn on the ignition switch without starting the engine and open the vapor withdrawal valve. Then remove the radiator cap and check the coolant for bubbles, which would mean that the converter has a leaking gasket.

For converter service, see your dealer.

SERVICING LP-GAS FUEL TANK, VALVES AND GAUGES

Be sure that you are familiar with all rules and regulations before servicing LP-Gas equipment.

Two rules are important here:

1. Never service the fuel tank except to remove and install valves or gauges.
2. Never service the valves or gauges except to remove and install them or to replace caps or dust covers.

ers. Your dealer should perform all major LP-Gas service.

Replacing Parts

If a valve or gauge is damaged or worn and must be replaced, first empty all fuel from the tank to remove the pressure. If possible, *do this outdoors by running the engine until all fuel is exhausted*. If not possible, consult your local LP-Gas distributor for the approved method in your locality for emptying the tank.

When replacing a valve, use a small amount of Permatex or similar sealer on the threads. Install the valve and tighten securely. Test for leaks by using soapy water. *Never use an open flame.*

For other information, see your machine dealer.

DIESEL FUEL SYSTEMS

INTRODUCTION

The prime job of the diesel fuel system is to inject a precise amount of atomized and pressurized fuel into each engine cylinder at the proper time (Fig. 28).

Combustion in the diesel engine occurs when this charge of fuel is mixed with hot compressed air. No electrical spark is used (as in gasoline engine).

The major parts of the diesel fuel system are:

- **Fuel Tank**—stores fuel

- **Fuel Transfer Pump**—pushes fuel through filters to injection pump
- **Fuel Filters**—clean the fuel
- **Injection Pump**—times, measures, and delivers fuel under pressure to cylinders
- **Injection Nozzles**—atomize and spray fuel into cylinders

These parts in a basic system are shown in Fig. 28.

OPERATION

In operation, fuel flows by gravity pressure from the FUEL TANK to the Transfer Pump (Fig. 28).

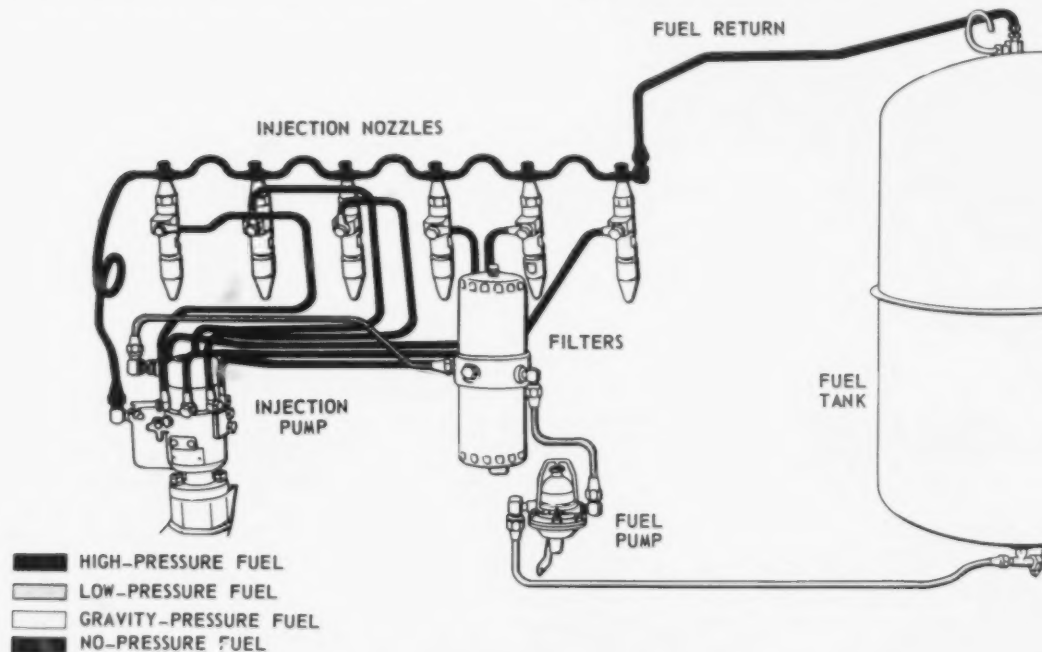
The TRANSFER PUMP pushes the fuel through the FILTERS, where it is cleaned.

The fuel is then pushed on to the INJECTION PUMP where it is put under high pressure and delivered to each Injection Nozzle at the exact time needed.

The INJECTION NOZZLES atomize the fuel and spray it into the combustion chamber of each cylinder.

Various kinds of injection systems are used on different engines. All systems have a low-pressure side and a high-pressure side as shown in Fig. 28. The low-pressure side is from the fuel tank to the injection pump. The high-pressure side is from the injection pump to the injectors. The high pressure created by the injection pump forces the fuel through the injectors, making a fine mist as fuel is sprayed into the cylinders.

Fig. 28—Diesel Fuel System (Distributor Type Shown)



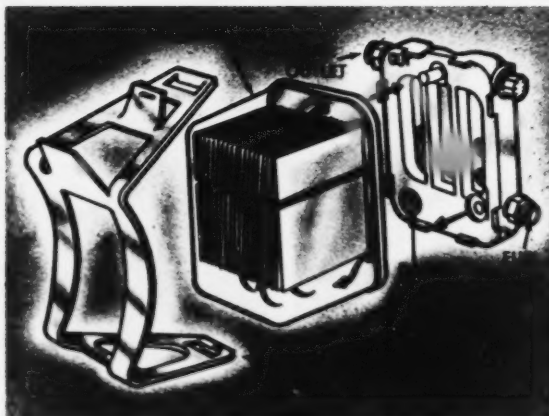


Fig. 29—Single-Stage Diesel Fuel Filter

The injection pump times and meters the injection of fuel into each cylinder at the precise moment for good combustion. Note that one type of injection system has a combination injection pump and nozzle which is actuated by a rocker arm similar to those that operate the intake and exhaust valves.

Most diesel fuel systems have a fuel return line which returns excess fuel from the injectors or from the injection pump to the fuel tank. The excess fuel is used on some systems to help cool and lubricate the pump and injectors.

Filter systems vary from one filter to three filters. If there is only one filter (Fig. 29) it must be serviced regularly and carefully because there are no other filters to help clean the fuel.

Additional filters, such as second-stage and third-stage filters, are often used to assure that water and dirt particles will be removed from the fuel (Fig. 30). Second- and third-stage filters also require careful attention, but at longer intervals.

IMPORTANCE OF SERVICE

The diesel fuel system requires careful service in order to keep it operating properly. *The injection pump and nozzles are precision parts which can be damaged by small particles of dirt or other contaminants.* Any damage to these parts is costly to repair. If dirt enters the injection pump, the pump will wear and poor fuel delivery will result. Dirt will also clog the injector nozzles and make them inoperable. Water is another enemy: it can rust these precision parts.

The injection pump and injector nozzles have very finely machined parts, with clearances as small as 0.0001 inch (0.0025 mm). These parts are necessary to develop and use the high pressures required at the nozzle tips so the engine will operate properly and efficiently.

Since these injection parts are so finely machined, they often must be serviced by the manufacturer, since some dealers are not equipped to service them. However, always check with your machine dealer first.

It is not possible to eliminate all moisture and dirt particles from the fuel. However, dirt and moisture can be reduced by good maintenance so that your engine will give thousands of hours of operation without repair to the injection pump or the injectors.

SERVICING THE DIESEL FUEL SYSTEM

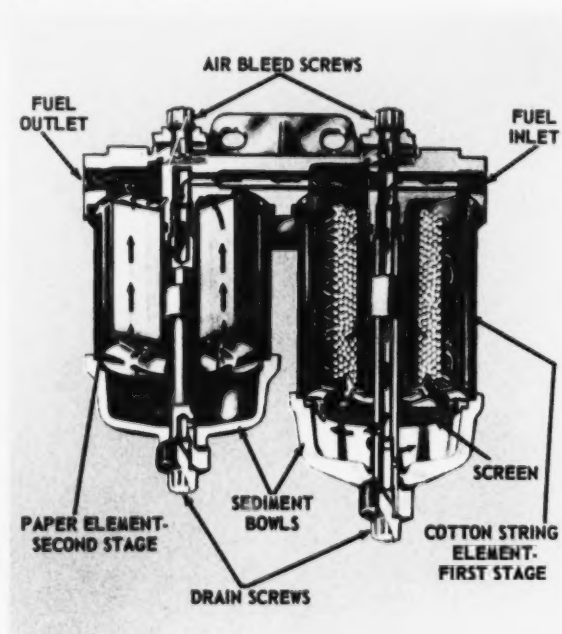
Because servicing the injection pump and injector nozzles require special tools and equipment, you should be mainly concerned with the other components, on the low-pressure side, such as the fuel filters, fuel sediment bowl and fuel tank. If these units are properly serviced, little trouble should be experienced with the injection pump and nozzles.

Tools and Materials Needed

To service the low-pressure side of the system, the following tools and materials are needed.

1. Clean, lint-free cloths
2. Container of cleaning solvent (not gasoline)
3. Container to catch waste fuel
4. Set of wrenches (inch or metric, as required)

Fig. 30—Two-Stage Diesel Fuel Filter



5. Small, soft bristle scrub brush
6. Replaceable filters, if needed

Importance of Water and Dirt Removal

Water and sediment can seriously damage a diesel fuel injection system. So, diesel engines have rather elaborate systems for removing such impurities from the fuel.

- a. Sediment grinds away the finely fitted parts of the injection pump.
- b. Water causes the parts to rust (a very small amount of rust can cause serious damage).
- c. Water interferes with the proper feeding of fuel and causes rough running of the engine.

Water is more of a problem in diesel fuel than it is in gasoline. Water separates from gasoline rather readily; but the weight of diesel fuel is so near the weight of water that they mix readily and separate slowly. With the machine motionless during the night, water has time to separate from the diesel fuel and settle to the bottom of the tank. The trapped water should be removed from the system each morning.

Machine manufacturers take advantage of this situation and have provided for removing the water as shown in Fig. 31 and Fig. 32.

Removing Daily Deposits of Water and Sediment

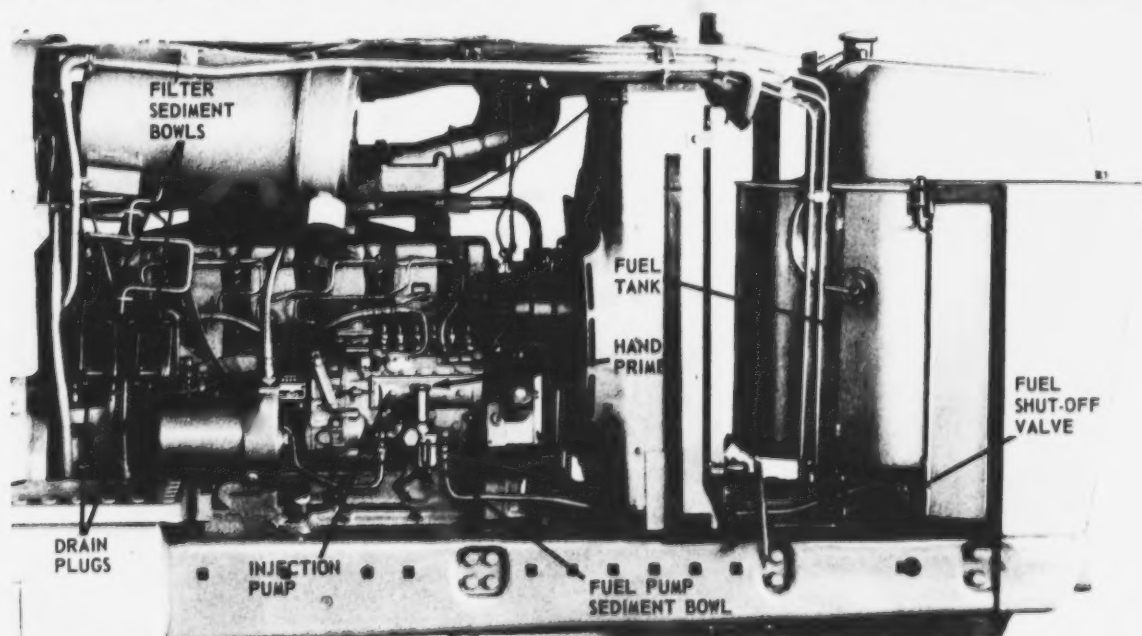
Use the directions in the operator's manual for your machine. Here are instructions for a typical unit:



Fig. 32—Drain For Fuel Tank Sump

1. If there is water or an excess of foreign matter in the fuel pump sediment bowl (Fig. 31), close the fuel tank shut-off valve and remove the sediment bowl.
2. Clean the bowl and strainer in solvent and wipe dry.
3. Install the bowl and strainer, using a good gasket.
4. Open the shut-off valve and bleed the filters by working the hand primer on the injection pump (see "Bleeding System," later).
5. If there is water or an excess of foreign matter at the bottom of a fuel filter bowl (Fig. 31), loosen the drain plug for that filter and drain the water or foreign

Fig. 31—Removing Daily Deposits From Diesel Fuel System



matter from the filter. Bleed the filters.

6. If water was present in the fuel pump bowl or a fuel filter bowl, drain all the water from the fuel tank to prevent the water from plugging the filter. A sump at the bottom of the fuel tank traps the water.

7. To drain the fuel tank sump, open the drain cock (Fig. 32).

Normally, only the fuel pump sediment bowl and the filter sediment bowls need to be checked every day. If they are clean, the system should be okay. If they are dirty, perform all the maintenance steps given above.

Servicing Fuel Filters

Refer to your operator's manual for the filter change interval. Normally, a first-stage filter should be changed every 500 hours, and the second-stage filter every 1000 hours, or each season. The condition of your fuel will determine whether or not you have to change more frequently.

Service the filters as follows:

1. Be sure fuel shut-off valve (Fig. 32) is turned off. Clean outside of filter and area surrounding filter.
2. Drain fuel from filter if the filter has a drain.
3. Remove filter or filter bowl. Filters may be held in place with one or more stud bolts or a clip (Fig. 33), or be of the spin-on type.
4. If the filter is not the disposable type, clean it in

Fig. 33—Removing Diesel Fuel Filter

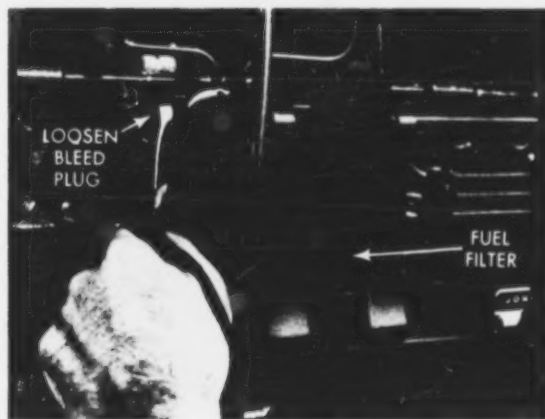


Fig. 34—Bleed Plug For Removing Air From Fuel Filters

a pan of cleaning solvent (not gasoline).

5. Inspect it for ruptures or damage. Replace element if it is not in excellent condition. Always replace a disposable filter (such as the one shown in Fig. 33).
6. Clean inside of filter bowl or body (unless it is a self-contained unit). Use a brush or lint-free cloth for cleaning. Be sure that it is absolutely clean.
7. Install cleaned filter or new disposable filter element. Be sure to use new gaskets where separate gaskets are used. Secure filter to filter body.
8. Replace or clean the second-stage filter if necessary. (The dual filters shown in Fig. 33 are replaced in pairs.)
9. Replace the drain plug or tighten the drain valve (if opened).
10. Open the fuel shut-off valve.
11. Bleed the fuel filters (see below).

Bleeding Air From Fuel System After Service

Each time you drain the fuel lines or filters, air is left in them. Unless removed, this air may form an air lock when you try to start the engine. This will prevent a normal supply of fuel from reaching the injection pump, and the engine may not start or may run poorly.

Before bleeding air, be sure fuel tank is nearly full to provide enough fuel and pressure to bleed the system.

Bleed air from the system as follows:

1. If you have changed more than one filter, bleed the filter closest to the fuel tank first.
2. Open bleed plug or plugs on top of filters (Fig. 34).
3. Open fuel supply valve. This will force air through the bleed plug and replace the air in the lines and filters with fuel (on gravity-flow systems). Some systems are equipped with a hand priming pump or lever to be



Fig. 35—Hand Priming Pump For Bleeding Air From System

used in removing air (Fig. 35). Push the hand primer several strokes until fuel free of air bubbles escapes from the bleed plug hole at the filters.

4. Close bleed plug after all air is removed from filters.

5. If air lock is still present (the engine may not start or will run poorly), you will also have to bleed the injection lines (Fig. 36). (Normally, you can bleed half the injection lines and the others will bleed themselves by running the engine until it runs smoothly).

CAUTION: Escaping diesel fuel under pressure can penetrate the skin, causing injury. Before disconnecting lines, be sure to relieve all pressure. Before applying pressure again, be sure that all connections are retightened after bleeding.

6. Loosen injection line nuts *only one turn* to avoid excessive spray. Use two wrenches as shown in Fig. 36 to avoid bending or twisting fuel line.

Fig. 36—Bleeding Injection Lines At Injectors (If Necessary)

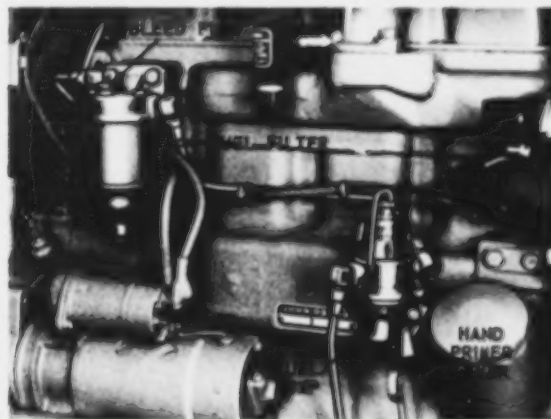
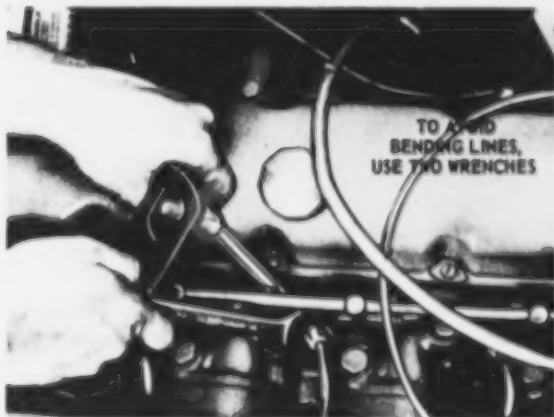


Fig. 37—Bleeding Air From Diesel Fuel System (Alternate System)

7. Crank the engine with the starter until fuel without foam flows around the connectors.

8. Carefully tighten the line connectors only until snug and free of leaks.

9. Start the engine and run it until it runs smoothly. This will bleed the other injectors.

NOTE: Some diesel fuel systems have a separate fuel pump with primer (Fig. 37). On these systems, loosen filter bleed plugs and pump out air using primer lever on pump. Then bleed air from lines if necessary.

Servicing Of Diesel Injection Pumps And Nozzles

Injection pumps and nozzles require special tools and equipment, so go to your dealer or service center for all adjustments and repair of precision injection units.

ENGINE GOVERNOR

The governor is a device which automatically controls the speed of the engine under varying loads (Fig. 38).

Governors do these jobs:

- Maintain a selected speed
- Limit the slow and fast speeds
- Shut down the engine when it overspeeds

Fig. 39 shows how the governor keeps the engine at a constant speed when the machine is going uphill or downhill.

The governor on the engine automatically regulates speed at whatever setting you select on the speed control (throttle) lever.

Most operator's manuals give detailed instructions on how to adjust the governor for high no-load speed. However, some manuals have no governor adjustment and others warn against making any adjustments.

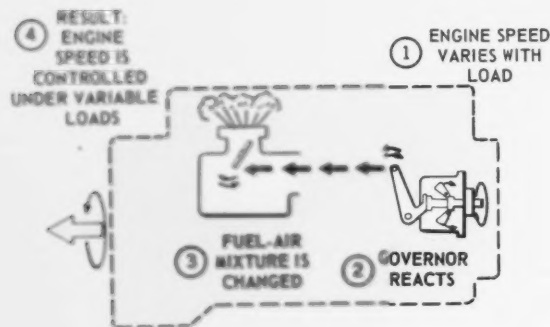


Fig. 38—Governing System (Gasoline Engine With Centrifugal Governor Shown)

Some engines have governors with the adjustments sealed inside the governor housing to discourage operators from making adjustments.

Since there is some question about whether operators should adjust governors, this discussion does not include procedures for doing the job. But it is intended to help you understand how a governor works, and the importance of proper governor adjustment. This understanding will be helpful whether you service it, or have it done by a competent serviceman.

Fig. 39—What The Governor Does For The Machine Engine



IMPORTANCE OF GOVERNOR ADJUSTMENT

Machine manufacturers test their engines and select a maximum speed for each model that provides satisfactory power in relation to fuel consumption, wear and other factors. The speed selected varies with different makes and models. The maximum idle speed recommended for your machine is given in the operator's manual. It is the one you normally use for checking your governor.

Your operator's manual may also give a full-load speed. It will be less than the high-idle speed even though the speed control lever is in the same position. As load is added, there is some loss of engine speed that the governor does not recover. For example, an engine that has a high no-load speed of 2700 revolutions per minute (rpm) may have a full-load speed of 2500 rpm. The speed loss is different with different engines.

- If a machine is operated much faster than the top speed specified, wear increases rapidly.
- If the engine is operated much slower than the manufacturer recommends, there is less power available and operating costs increase.

If only one high no-load speed is given, the governor is usually considered as being in satisfactory adjustment if the top engine speed is within 20 rpm (faster or slower) of that speed. However, some manuals will indicate a speed range such as 2500 to 2600 rpm. The governor is considered to be in proper adjustment if the high idle speed is within this range.

OPERATION OF GOVERNOR

After you set the speed control lever, the job of the governor is to adjust the amount of fuel-air mixture (fuel only for diesel engines) that the engine receives so the engine speed remains approximately the same even though the load varies. Consequently, the governor must be sensitive to speed changes. Fig. 39 shows a simplified governor control. Note that the governor is mounted on the engine camshaft where it is directly affected by any slight change in engine speed.

On **carburetor (spark-ignition) engines**, the governor controls the fuel-air mixture by opening and closing the throttle (butterfly) valve. When you open the **speed-control lever** (Fig. 40), tension is exerted on the **governor control spring**. The spring tension turns the **governor lever** clockwise, opening the **throttle valve**. More fuel-air mixture can enter the engine, causing it to speed up.

But when the engine speeds up, centrifugal force acts on the **flyweights** pushing them outward (Fig. 40). They are hinged so that when they move outward, the **governor drive plate** is pushed out. This rotates the **governor arm** which, in turn, moves the **governor lever** in a counter-clockwise direction. As a result, the butterfly valve tends to close. This would slow the engine

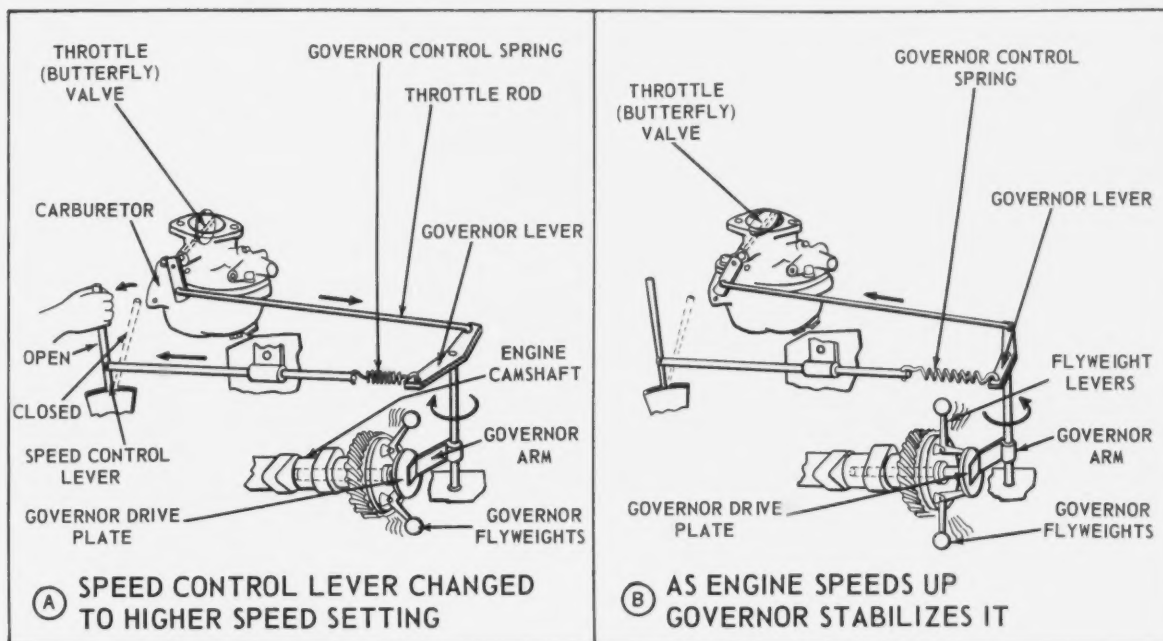


Fig. 40—Operation Of Governor In Controlling Engine Speed

speed except for the tension of the *governor control spring*. But a balance is reached immediately between the force of the flyweights and the tension of the governor control spring. This balance holds the throttle valve at the proper position to maintain a constant engine speed.

Let's assume *more load is put on the engine*. The engine speed slows, centrifugal force is reduced on the flyweights and they pull in. This removes some of the pressure on the *drive plate* against the *governor arm*, allowing spring tension to turn the *governor lever* in a clockwise direction (Fig. 40). The throttle valve opens further, allows more fuel-air mixture into the engine and increases horsepower output (lugging power) without increasing engine speed.

With the throttle valve open further, more fuel-air mixture is fed to the engine. Engine speed tends to increase but any increase in speed causes the flyweights to move out, overcoming enough spring tension to set up a new balance between the governor and the governor control spring which keeps the engine speed constant.

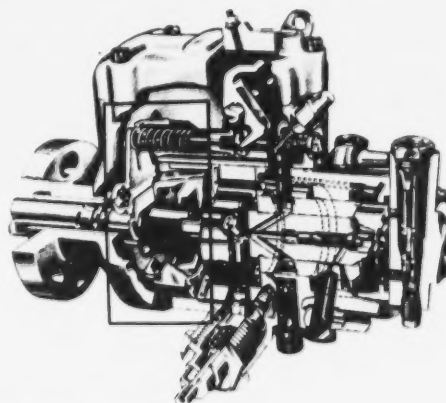
At higher engine speeds your machine has the capacity to meet a wide range of power demands. This is why it is important to set the speed control lever at high enough speed to take care of the maximum power needed for a job. When you do this, the engine is ready to start lugging the governor action feeds more fuel into it. If your setting is too low, there is not enough tension on the governor spring to allow the engine to come up to full power.

GOVERNING OF DIESELS

The operating principle of the governor on a **diesel engine** is the same as that for a spark-ignition engine, except the diesel engine governor controls only the fuel going to the engine. This is done by various means, such as: an arrangement that shortens or lengthens the stroke of the injection pump to meet varying load conditions ((Fig. 41); or a master valve that meters the fuel supply to meet the varying power demands.

The built-in centrifugal governor in a typical diesel injection pump is shown in Fig. 41.

Fig. 41—Governor In Diesel Injection Pump



MAINTAINING THE GOVERNOR

A governor in proper condition will respond quickly to a change in load conditions and will maintain the correct engine speed without surging. Note the delicate balance that exists between the governor control spring and the governor flyweights. If the spring loses tension, if the governor parts wear or if any of the linkage that connects the mechanism starts to bind, the governor will not work properly.

Check the operator's manual for guidance on whether you should attempt to adjust it or take it to a serviceman.

CHAPTER QUIZ

1. (Fill in blank.) Gasoline fuels with higher octane ratings have the least tendency to produce _____ in the engine.
2. Match the two items at left with the definitions at right.

A. No. 1-D Diesel Fuel	1. Used in high-speed engines in services involving relatively high loads and uniform speeds.
B. No. 2-D Diesel Fuel	2. Used in high-speed engine in services involving frequent and relatively wide variations in loads and speeds.
3. What causes knock in diesel engines?
 - A. The fuel igniting too slowly.
 - B. The fuel igniting too fast.
4. In what order should the following carburetor (gasoline) adjustments be made?
 - A. Load fuel-air mixture
 - B. Idling fuel-air mixture
 - C. Idling speed
5. Name the four basic parts of an LP- Gas fuel system.
6. Name two gases that are combined to make LP-Gas.
7. What is the number one enemy of the diesel fuel system?
8. Name the three jobs of the engine governor.
9. What are the three basic parts of the low pressure fuel system on a diesel?
10. What part of a diesel fuel system will require the most service by the operator?

4

Engine Lubrication Systems



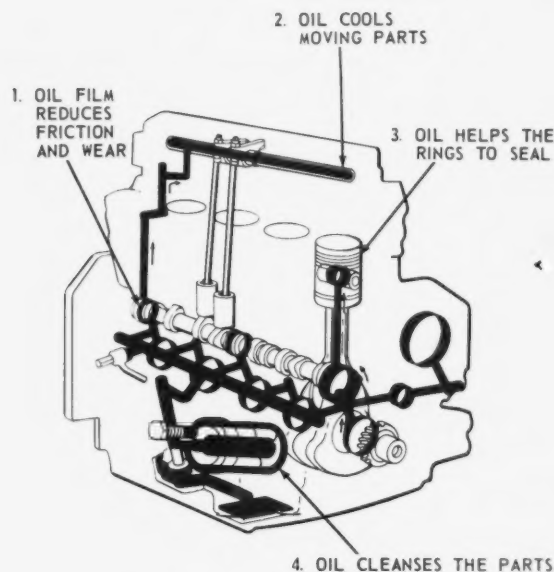


Fig. 1—Lubricating System On Typical Engine

INTRODUCTION

When agricultural engines were first used, you could have lubricated the engine with an oil can and a single type of oil. Most oil was supplied in three grades—light, medium and heavy.

But in today's high-speed engines, all this has changed. Speeds, pressures, and temperatures have all increased.

Special oils have been developed for each type of engine, for each type of machine, and for each season.

As a result, lubrication has changed from a simple chore to a science of preventive maintenance.

WHAT ENGINE OILS MUST DO

To keep today's engines running, engine oils must:

- Reduce friction and wear
- Cool moving parts
- Help seal the cylinders
- Keep the parts clean

To do these jobs, engine oil must also:

1. Keep a protective oil film on moving parts.
2. Resist high temperatures.
3. Resist corrosion and rusting.

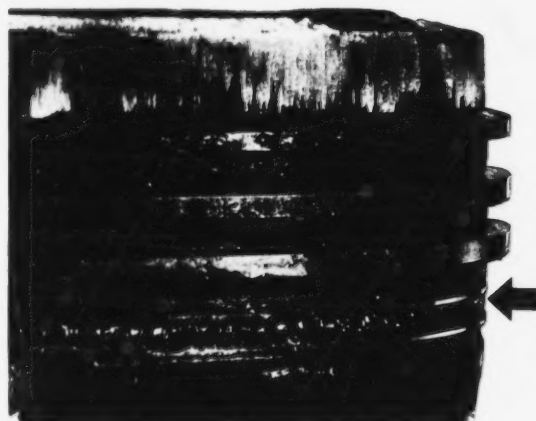


Fig. 2—Effect Of Poor Maintenance—Piston Oil Control Ring Plugged By Oil Sludge

4. Prevent ring sticking.
5. Prevent sludge formation.
6. Flow easily at low temperatures.
7. Resist foaming.
8. Resist breakdown after prolonged use.

IMPORTANCE OF SERVICE

CHANGING ENGINE CRANKCASE OIL

Oil loses many of its good lubricating qualities as it gets dirty and its additives wear out. Acid formations, sludge, varnish, and engine deposits contaminate oil and make it unfit for continued use. This in turn can harm vital engine parts (Fig. 2).

On the other hand, just because crankcase oil is black, doesn't mean it's time for an oil change. Additives in the oil are supposed to clean and hold deposits in suspension for removal when the oil is drained.

Changing the oil at a time BEFORE the additives wear out will protect the engine against sludge. For the operator, this time is practically impossible to determine. That's why the best policy is to follow the manufacturer's recommendations on oil and filter changes.

New or rebuilt engines require oil and filter changes after a specified *break-in period*. Performing this service on time is very important, since foreign materials accumulate in the oil at a faster rate during initial operation than when the engine is broken in.

When changing the oil and filter on any engine, always warm up the engine first. This way the contaminants and foreign materials are mixed with the oil and are drained out with it.

Replacing some oil filters requires installing new gaskets or sealing rings. Be sure the sealing surfaces on



Fig. 3—Record All Oil And Filter Changes

the engine and filter are clean.

After installing the filter and filling the engine with oil, run the engine and check for possible filter leaks.

Keep a maintenance record of all oil and filter changes to be sure of regular engine service. Some operator's manuals provide a chart for such record keeping, or use a sticker on the cab window or hood as a reminder (Fig. 3).

PREVENTING CONTAMINATION OF OIL

Oil contamination will reduce engine life more than any other factor. Some sources of contamination are obvious while others are not.

Let's review some of these sources of contamination and what can be done about them.

1. The most obvious source of contamination is the *storing and handling of the oil itself*. Store lubricants in a clean, enclosed storage area. Keep all covers on and cap the spouts on containers when not in use. These practices not only keep dirt out of the oil, but also reduce condensation of water caused by atmospheric changes.

2. Another obvious source is *dust that is breathed into the engine* with combustion air. It is very important that the air cleaner be cleaned or replaced regularly (see Chapter 2).

3. A major source of contamination is a *cold engine*. When the engine is cold, its fuel burning efficiency is greatly reduced. Partially burned fuel blows by the piston rings and into the crankcase. Oxidation of this fuel in the oil forms a very harmful varnish which collects on engine parts.

To help prevent this, be sure the thermostat is working to provide fast engine warm-up (see Chapter 5). An overchoked or misfiring engine will also create contamination from unburned fuel.

Water created by a cold engine contaminates the oil too. Water vapor, a normal product of combustion,

tends to condense on cold cylinder walls. This condensation is also blown by the rings into the crankcase. The engine must warm up before this condensation problem is eliminated.

Water not only causes rusting of steel and iron surfaces, but it can combine with oxidized oil and carbon to form sludge. This sludge can very effectively plug oil screens and passages.

Contamination from a cold engine can be prevented by:

- (a) Properly warming up the engine before applying a load.
- (b) Making sure the engine is brought up to operating temperature each time it is used.
- (c) Using the proper thermostat in the cooling system to warm up the engine as quickly as possible.

4. *Antifreeze* can be another sludge-forming source of contamination. It can also dilute the oil. To guard against antifreeze contamination:

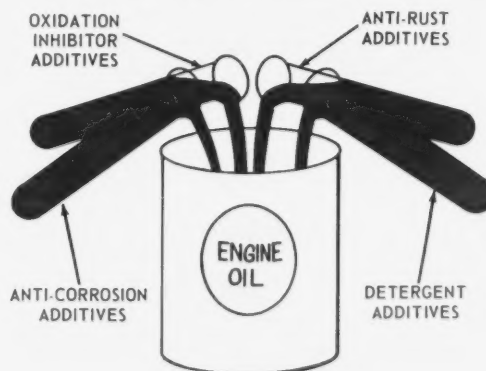
- (a) Tighten cylinder head bolts to specified torque during an overhaul.
- (b) Periodically check the cooling system for internal leaks (see Chapter 5).
- (c) Guard against detonation and improper use of starting fluids in diesel engine (both can result in head gasket damage).

Other problems can also cause oil contamination:

5. *Oxidation* is not an obvious source of contamination, but is a very real one. Oxidation occurs when the hydrocarbons in the oil combine with oxygen in the air to produce organic acids. Besides being highly corrosive, these acids create harmful sludges and varnish deposits.

6. *Carbon* particles are another contaminant created by the normal operation of the engine. The particles are created when oil around the upper cylinder walls

Fig. 4—Good Quality Oil Already has Important Additives



is burned during combustion. Excessive deposits can cause the piston rings to stick in their grooves.

7. Engine wear creates contaminants. Tiny metal particles are constantly being worn off bearings and other parts. These particles tend to reduce the oil's effectiveness.

All sources of contamination cannot be eliminated. **What, then, can be done to protect the engine?**

Start by using a good-quality oil with the proper **additives** (Fig. 4). Additives are put in the oil for a specific reason, based on the service expected for the oil.

Here are some of the important additives:

ANTI-CORROSION ADDITIVES protect metal surfaces from corrosive attack. These work with oxidation inhibitors.

OXIDATION INHIBITOR ADDITIVES keep oil from oxidizing at high temperatures. They prevent the oil from absorbing oxygen, thereby preventing varnish and sludge formations.

ANTI-RUST ADDITIVES prevent rusting of metal parts during storage periods, downtime, or even overnight. They form a protective coating which repels water droplets and protects the metal. These additives also help to neutralize harmful acids.

DETERGENT ADDITIVES help keep metal surfaces clean and prevent deposits. Particles of carbon and oxidized oil are held suspended in the oil. The suspended contaminants are then removed from the system when the oil is drained. Black oil is evidence

that the oil is helping to keep the engine clean by carrying the particles in the oil rather than letting them accumulate as sludge.

However, remember that *additives eventually wear out*. To prevent any problems, drain the oil *before* the additives are completely depleted. Your operator's manual will tell you when you should change oil. However, watch both the hours of operation *and* the elapsed time. Some additives in oil lose their effectiveness after a period of time, even if the engine has not been operated much.

Also service engine oil filters at recommended intervals. This is usually at the same time the crankcase oil is drained and replaced.

If you use quality oil of the type recommended for the engine, other additive compounds should normally *not* be added to the engine crankcase.

Buy oil only from the manufacturer of your engine or from a reliable oil supplier. Be wary of claims of "miracle" additives, or oils which "won't wear out." Such oils could damage your engine and void the engine warranty.

Finally, keep the fuel, cooling, ignition, intake, and exhaust systems in good condition so that the fuel is efficiently burned.

OPERATION OF LUBRICATION SYSTEM

The major parts of the system are:

- Oil Pump
- Crankcase
- Oil Cooler (if used)
- Oil Filter
- Pressure Regulating Valve
- Pressure Gauge

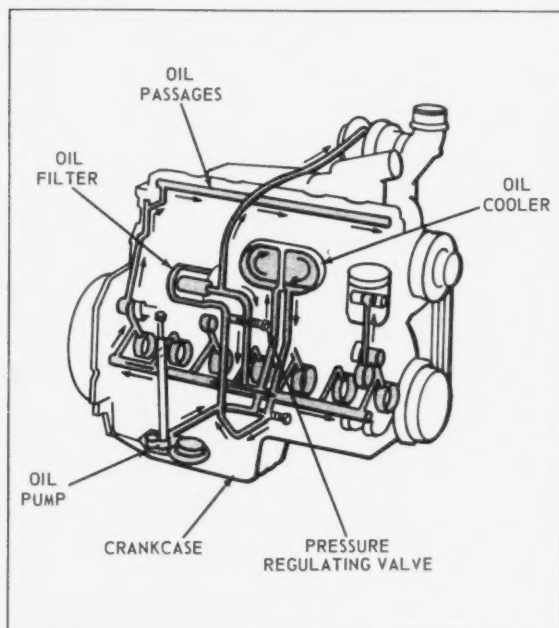
The OIL PUMP pushes oil through the system (Fig. 5). A reserve of oil is stored in the CRANKCASE for circulation through the system. At the OIL FILTER, dirt is taken out of the oil to help keep it clean. OIL PASSAGES take the oil to engine parts where they can provide lubrication and cooling and carry away dirt and deposits. Pressure of the oil is regulated by the PRESSURE REGULATING VALVE, which is usually adjustable. After oil moves through the whole system it comes back to the crankcase reservoir again. Finally, the PRESSURE GAUGE tells the operator if engine oil pressure is normal.

The system described above is a full force feed type. Let's now look at the major types of systems.

TYPE OF SYSTEMS

An engine lubricating system may be classified as:

Fig. 5—Major Parts of Engine Lubricating System



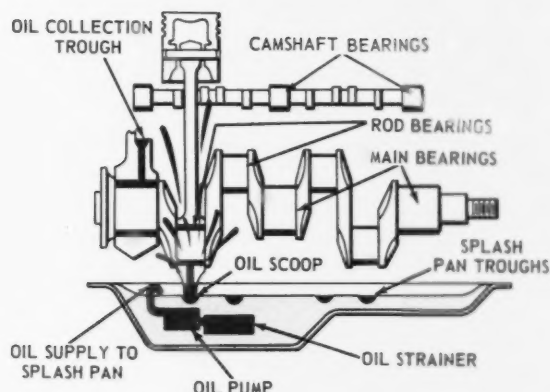


Fig. 6—Circulating Splash System

- Circulating Splash
- Internal Force Feed and Splash
- Full Internal Force Feed

The type of system used depends largely upon the size and design of the engine.

Circulating Splash System

In the *circulating splash* system an oil pump supplies oil to a splash pan located under the crankshaft (Fig. 6). As the connecting rods revolve, scoops on the ends

of the rods dip into troughs in the splash pan, creating the oil splash.

The splashing oil lubricates the moving parts nearby. Other parts are lubricated more by oil mist than by the oil splash itself. This mist is created as the connecting rods spin.

The *circulating splash* system must have:

1. Proper oil level in the pan
2. Suitable oil for good splashing

There must be enough oil in the troughs of the splash pan for the connecting rods to splash. The oil pump must be working properly to provide this oil.

Because the oil must splash and flow freely, heavy oil will not work. Use only oil of the viscosity recommended by the engine manufacturer.

This system is used mainly on smaller engines.

Internal Force Feed and Splash System

In the *internal force feed and splash* system, the pump forces oil directly to a main oil gallery in the engine block rather than to a splash pan.

From the main oil gallery, the oil is forced through passages to the main bearings, connecting rod bearings, camshaft bearings, rocker arm shaft, filter, and pressure sending unit.

The oil escaping from the bearings creates a mist which also lubricates the upper cylinder walls, pistons, and pins.

Pressure of the lubricating oil can usually be adjusted in these systems.

Full Internal Force Feed System

The *full internal force feed* system goes one step farther than the system above. Oil is forced not only to the crankshaft bearings, rocker arm shaft, filter and pressure sending unit, but also to the piston pin bearings.

The piston pin bearings are lubricated through drilled passages in the connecting rods (Fig. 7). The cylinder walls and pistons are lubricated by oil escaping from the piston pin bearings or the connecting rod bearings.

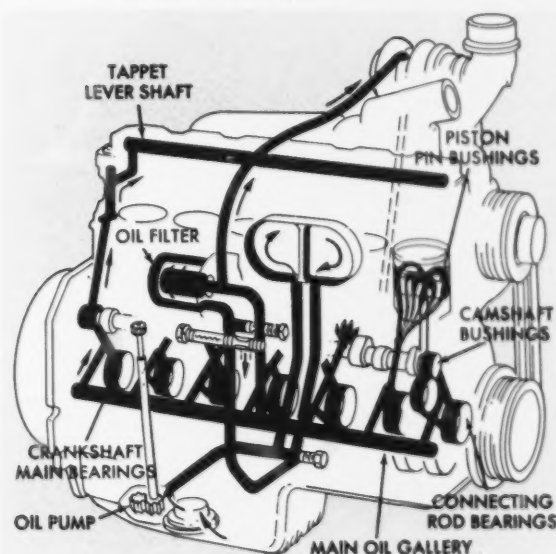
The *force feed* system has one prime need: **GOOD OIL PRESSURE.**

As the force feed system requires oil to be pumped long distances and through many passages, sufficient oil pressure is required. The required pressure for most engines is 25 to 40 psi (170 to 275 kPa), but it may go as high as 65 psi (450 kPa). If the oil pressure drops too low on the gauge, shut off the engine immediately and find the cause.

Oil pressure is normally adjusted at a pressure regulating valve (shown in Fig. 7).

This type of system is widely used in today's agricultural engines.

Fig. 7 — Full Internal Force Feed System



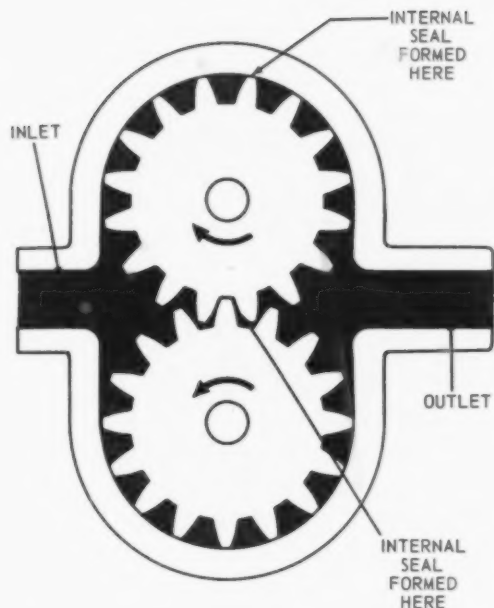


Fig. 8—Engine Oil Pump In Operation

OIL PUMP

Pumps for engine lubrication are usually gear types, mechanically driven by the engine. Usually the pump is driven from the camshaft or from the crankshaft. In some large engines, an electric motor is used to drive the auxiliary pump.

The pumps push oil through the system and also trap it so that normal pressure can be built up in the system.

The common *external gear pump* has two gears in mesh, closely fitted inside a housing (Fig. 8). The drive shaft drives one gear, which in turn drives the other gear. The machined surfaces of the outer housing are used to seal the gears.

As the gears rotate and come out of mesh, they trap inlet oil between the gear teeth and the housing. The trapped oil is carried around to the outlet chamber. As the gears mesh again, they form a seal which prevents oil from backing up to the inlet. The oil is forced out at the outlet and sent through the system.

OIL FILTERS AND FILTRATION SYSTEMS

Oil contamination reduces engine life more than any other factor. To help combat this, oil filters are designed into all modern engine lubricating systems.

Let's look first at the two basic types of filters, then at two types of filtering systems.

Types of Filters

Filters are classified as either *surface-type* filters or

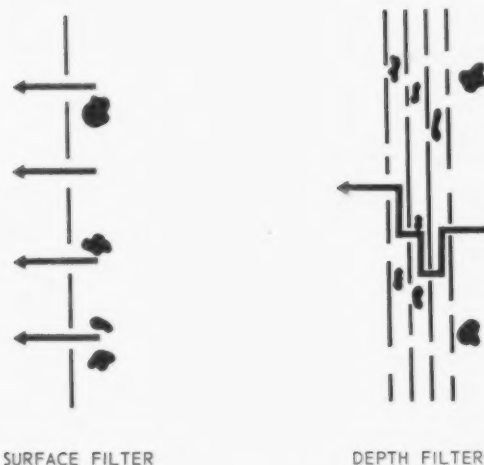


Fig. 9—Surface And Depth Filters Compared

depth-type filters depending on the way the oil moves through them (Fig. 9).

SURFACE FILTERS have a single surface that catches and removes dirt particles larger than the holes in the filter. Dirt is strained or sheared from the oil and stopped outside the filter as oil passes through the holes in a straight path. Many of the large particles will fall to the bottom of the reservoir or filter con-

Fig. 10—Wire Mesh Filter



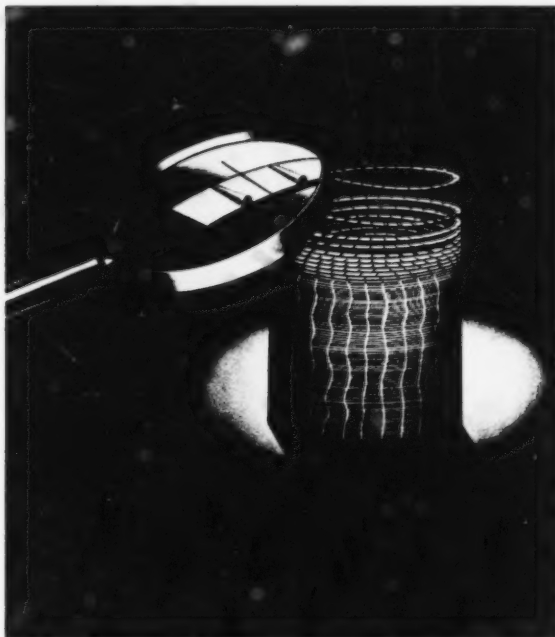


Fig. 11—Metal Edge Filter

tainer, but eventually enough particles will wedge in the holes of the filter to prevent further filtration. Then the filter must be cleaned or replaced.

A surface filter may be made of fine wire mesh (Fig. 10), stacked metal or paper disks, metal ribbon wound edgewise to form a cylinder (Fig. 11), cellulose material molded to the shape of a filter, or accordion-pleated paper (Fig. 12).

DEPTH FILTERS, in contrast to the surface type, use a large volume of filter material to make the oil move in many different directions before it finally gets into the lubrication system. The filter made of cotton waste shown in Fig. 13 is an example of a depth filter.

Fig. 12—Pleated Paper Filter

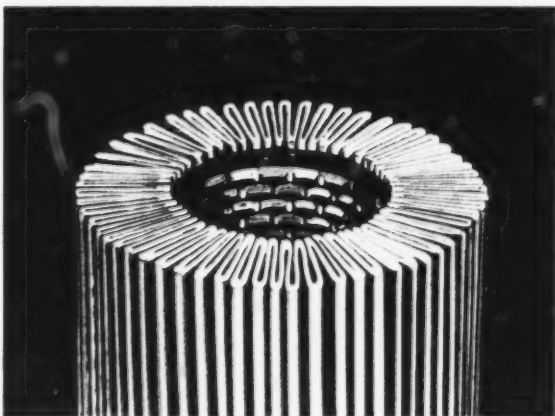


Fig. 13—Depth Filter (Cotton Waste Type)

Now let's look at the complete filtration system.

Types Of Filtration Systems

There are two types of oil filtering systems. They are:

- (1) *By-pass system.*
- (2) *Full-flow system.*

Both are shown in Fig. 14. Note in Fig. 14A that in the *by-pass system* only a portion of the oil moves through the filter as it leaves the pump. The rest goes directly to the engine bearings. With this type only about 1/10th to about 1/30th of the oil is by-passed through the filter at any one time. As the filter becomes contaminated, less of the oil goes through and more goes around.

With the *full-flow system*, as shown in Fig. 14B, all of the oil moves through the filter unless it is partly or completely blocked because of a dirty filter or cold oil. In that case, oil pressure builds up in the filter until the bypass valve is forced open, permitting unfiltered oil to flow around the filter and directly to the engine bearings. This protects the engine against loss of needed oil.

The full-flow filter, as part of an internal force-feed system, is used on most modern agricultural engines.

OIL COOLERS

Lubrication systems of many engines use an oil cooler to help remove the heat created by the engine. Most coolers are the oil-to-water cooling type, using engine coolant to dissipate unwanted heat

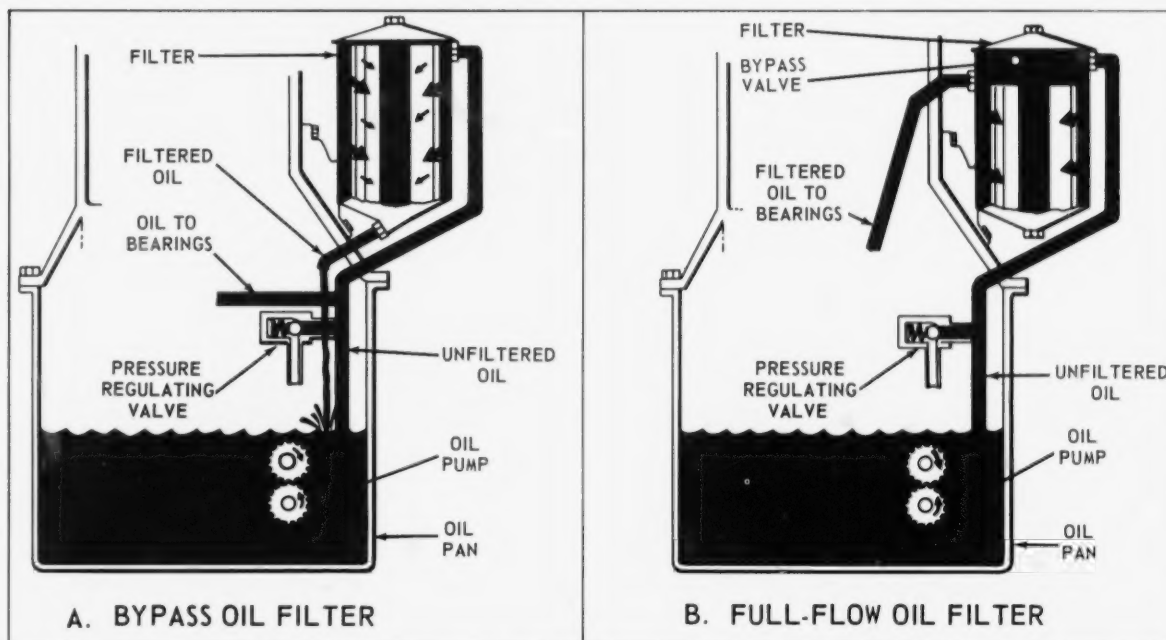


Fig. 14—Two Types Of Engine Oil Filters Compared

from the engine crankcase oil.

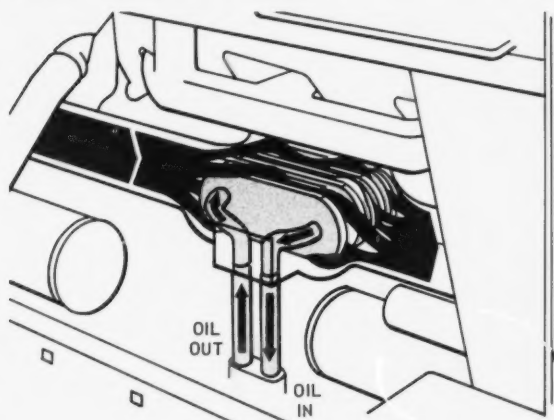
The oil cooler may be mounted inside the crankcase or on the outside of the engine block.

The full-flow filter as part of an internal force-feed system is used on most modern agricultural engines.

Operation Of Oil Cooler

As shown in Fig. 15, coolant circulates around the plates in the cooler, while the engine oil flows inside the plates. Heat from the oil is conducted through the plates to the coolant, which carries it to the radiator for dissipation.

Fig. 15—Operation Of Engine Oil Cooler



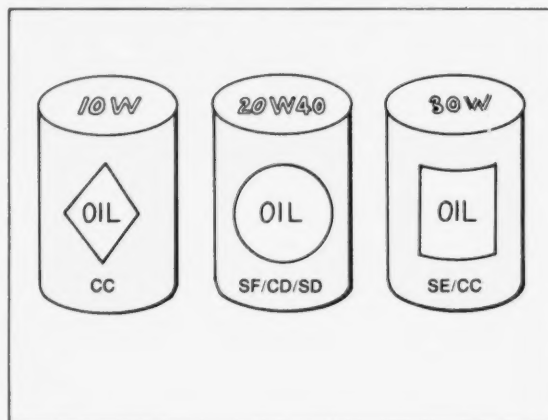
Another cooler (not shown) uses a small radiator core. The oil is pumped through the core and coolant is circulated around it.

A bypass valve is used with some oil coolers to assure circulation of the oil if the cooler should become clogged.

SELECTING ENGINE OILS

If you are to receive the best performance possible

Fig. 16—Selecting An Engine Oil



from a machine, you must use lubricants of the highest quality. The savings to be gained with lower-quality oils are at best small in relation to your over-all operating costs.

How can you be assured of obtaining an oil of high quality and one that's right for the job?

First, follow your operator's manual recommendations for engine oil (Fig. 16).

Second, choose oil from a reliable supplier—a reputable brand of oil.

To select the proper oil, you must be able to identify it. Descriptions such as "viscosity" and "service classification" are used to identify types of engine oils.

The Society of Automotive Engineers (SAE) has established the **Viscosity** designation which is a measure of the *fluidity of an oil at a given temperature*.

The American Petroleum Institute (API) established the **Service Classification** designation which identifies the *engine service design of the oil*.

Let's look at how oils are rated by these two organizations.

SAE VISCOSITY

As we stated, SAE rates the oil viscosity—or ability to flow at a given temperature. The lighter or more fluid oils intended for winter use are specified at 0°F (-18°C) and carry a 5W, 10W, or 20W symbol. Heavier oils for warmer operation are specified at 210°F (99°C) and carry SAE 30 and 40 symbols.

Oils vary in viscosity as temperatures change—becoming more fluid as temperatures increase and less fluid as temperatures decrease. The temperature effect on viscosity is not the same for all oils, and a measure of this is often important to the user.

Fig. 17—A Multi-Viscosity Oil Can Replace Several Single Viscosity Oils (When Recommended)

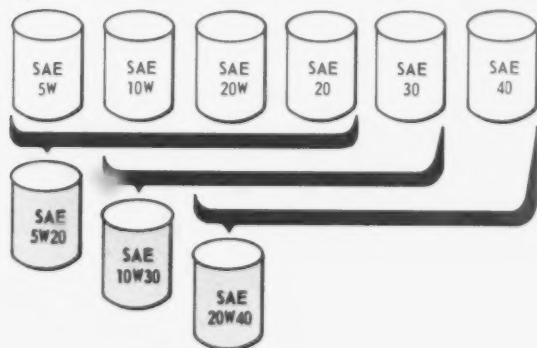


Fig. 18—Viscosity Is Marked On Oil Containers

Some oils are compounded to behave as light oils at cold temperatures, and as heavier oils at high temperatures. These oils are called **multi-viscosity oils** and include, for example, 10W-30 (Fig. 17). Where recommended, one multi-viscosity oil can replace as many as four or five single-grade oils.

Multi-viscosity oils can give protection at both high and low temperatures. However, multi-viscosity oils are primarily intended for use during seasons in which both extreme cold and warm periods occur. They are *not* usually recommended for use in warm weather in medium to heavy-duty applications.

SAE viscosity numbers are widely used as a means of identifying and classifying lubricating oil, and today are found on practically all cans or drums of oil marketed in the United States (Fig. 18).

Each number indicates a permissible range or limit of viscosity at specified temperatures. No attempt is made to define the oil's quality, additive content, performance value or suitability for specified service conditions. Therefore, the SAE viscosity should not be the only factor considered when selecting an oil.

Fig. 19 shows one equipment manufacturer's oil viscosity recommendations for four-cycle engines operating at various temperature levels. Note the upper temperature limits recommended for multiviscosity oils in industrial equipment applications.

API SERVICE DESIGNATIONS

The API system is an attempt to clarify the oil specifications and better define oil qualities between the engine manufacturer, the petroleum industry, and the customer. It is a joint effort of the API, ASTM (American Society for Testing Materials), and SAE organizations. Lubricants meeting more than one classification can be so marked.

The API chart which follows gives a brief designation for the SAE family of "S" and "C" designations and

what it means in terms of API identification of engine service expected of the oil.

API Service Designations For Engine Oils

SAE Letter Designation	API Identification Of Engine Service
SC	1964-67 Gasoline Engine Warranty Service
SD	1968-71 Gasoline Engine Warranty Service
SE	1972 Gasoline Engine Warranty Service
SF	1980 Gasoline Engine Warranty Service
CB	Gasoline and Naturally Aspirated Diesel Engine Service
CC	Lightly Turbocharged Diesel and Gasoline Engine Service
CD	Turbocharged Diesel Engine Service

A summary of all current recommendations, current common names, and new Performance Classifications is given in the following chart. The U.S. Army also has military (MIL) specifications which parallel some of the API designations.

The chart in Fig. 20 shows a typical oil service recommendation for an agricultural machine with either a

diesel or spark-ignition engine. Notice that diesel fuel quality affects this oil recommendation.

AGRICULTURAL VS. AUTOMOTIVE ENGINE OILS

Agricultural machines operate almost continuously under full loads, at constant speeds, over long periods of time (Fig. 21).

By comparison, automotive and light truck engines have lighter loads and more idling and stop-and-go driving conditions.

As you can see, each application is very different. For this reason, engineers have recently developed engine oils specifically for off-the-road farm and industrial machines.

If the operator's manual recommends a special engine oil, the engine will probably perform better with that oil than with any other—use it if at all possible.

STORING AND HANDLING ENGINE OILS

Use care in storing and handling oil to keep out dirt and moisture.

Store oil inside whenever possible—in clean, closed cabinets or rooms. It is best to keep oil relatively warm in the winter. Rapid changes in temperature can draw water into oil barrels if stored outside.

If stored outside, lay barrels on their sides. If they cannot be laid on their sides, tilt them slightly and turn the barrel so that the bung is at the high side, away from any water which might collect.

SUMMARY OF CURRENT EQUIPMENT MANUFACTURER RECOMMENDATIONS—ENGINE OILS			
Application	Oil Recommendations		Comments
	API Performance Classification	Common Current Name	
Gasoline Engine, Passenger Car	SE ¹ SF ¹	—	Meets warranty requirements of passenger car manufacturers.
Gasoline Engine, Truck, Bus, and Off Highway	CC SE ¹ SF ¹	MIL-B —	Principally concerned with heavy duty, some applications may require improved low temperature performance of SF and SE.
Diesel Engine, Truck and Bus	CB CC CD ²	Supplement 1 MIL-B Series 3 (S-3)	Recommendation of performance level involves consideration of engine design factors as well as application.
Diesel Engine, Off Highway	CB CC CD ²	Supplement 1 MIL-B Series 3 (S-3)	Recommendation of performance level involves consideration of engine design factors as well as application.

1. Oils meeting the performance requirements of MIL-L-46152B meet the performance requirements of SE, CC, and SF.

2. Oils meeting the performance requirements of MIL-L-2104C meet the performance requirements of both CD and SC.

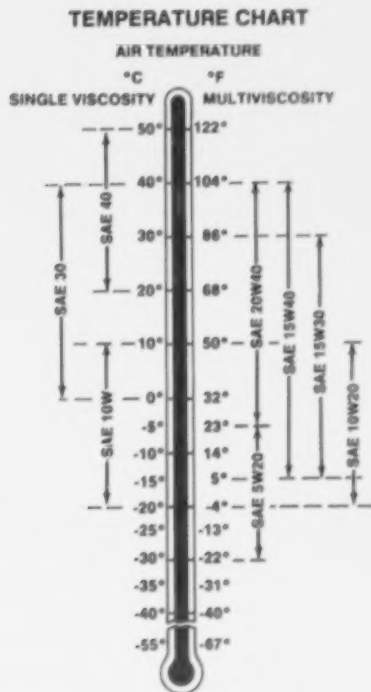


Fig. 19—Typical Oil Viscosity Recommendations At Various Temperature Levels

Keep oil bungs drawn tight. Use wooden mallets to make sure.

Rinse oil containers and funnels in fuel after use. Cover them to keep out dirt, or store them upside down.

When adding oil, clean all dirt from around the filler cap before removing it. (Do the same before unscrewing an oil filter or a filter cap.)

SERVICING THE LUBRICATING SYSTEM

You must service the engine lubricating system regularly to prevent premature wear and engine damage. This service consists mainly of checking crankcase oil level daily and changing the oil and filter at the proper intervals.

OIL SERVICE TYPE CHART	
SINGLE VISCOSITY OILS	
DIESEL ENGINES API Service CD/SD MIL-L-2104C* Series 3*	GASOLINE ENGINES API Service SF/CC/CD, CD/SE, CD/SD, CC/ SD or SD MIL-L-46152 MIL-L-2104C*
MULTI-VISCOSITY OILS	
DIESEL AND GASOLINE ENGINES	
API Service SF/CC/CD, CC/SE, CC/SD or SD	

* As further assurance of quality, the oil should be identified as suitable for API Service Designation SD

Fig. 20—Oil Service Chart

CHECKING CRANKCASE OIL LEVEL (DAILY)

Check the crankcase oil level **daily** (Fig. 22).

Don't check the oil level while the engine is running. Try to allow 10 minutes for oil to drain down after engine is stopped.

Remove the dipstick as shown and wipe dry with a clean cloth. Then insert fully and withdraw to check oil level.

Look at the top and bottom marks, which may be labeled "FULL" and "ADD". (Some manufacturers make the dipstick short so that when no oil shows it is time to add.)

Add oil if needed. If oil is down to lower mark, add recommended oil (usually one quart [one liter]) to fill to upper mark on dipstick.

Be sure oil and container are clean.

Don't overfill; this can cause oil consumption and foaming.

CHANGING CRANKCASE OIL AND FILTER

The oil in the crankcase of your engine should be changed every 100 hours or as recommended (refer to your operator's manual for specific times). Periods vary from 60 to 300 hours. Changing the oil filter is usually recommended at the same time. Be sure to change the oil and the filter more often if operating in extremely dirty or dusty conditions.



Fig. 21—Agricultural Machines Don't Work Like Automobiles—
And May Need Special Engine Oils

Tools and Materials Needed

1. Wrenches for crankcase drain plug and filter cap if needed (inch or metric, as required).
2. Clean, lint free cloths.
3. Cleaning solvent (not gasoline).
4. New oil of grade and type recommended to your engine and anticipated temperature.
5. New oil filter cartridge.
6. Container to watch waste oil.

Procedure For Changing Engine Oil and Filter

To change the oil in the crankcase, proceed as follows:

1. Operate the engine until it is thoroughly heated. This permits the oil to drain more completely. More contaminants are removed while the oil is still agitated. If the oil is drained while cold, contaminants may remain in the engine.
2. Shut off the engine and remove the drain plug (Fig. 23). Magnetic drain plugs may have metal particles on them. Strike the plug against a solid object to remove the particles. Be careful not to damage threads.
3. Allow the oil to drain for several minutes (Fig. 24). This permits oil to drain completely from various parts of the engine.
4. Wipe dirt from filter and surrounding area.
5. Loosen filter bowl or cover and remove (Fig. 25, page 68). (If the filter has a drain plug, remove the plug and allow the filter to drain before removing.)

IMPORTANT: Engine must be stopped while filter is removed.

6. Remove old filter cartridge and discard it.
7. Clean inside of filter bowl and base with solvent (not gasoline) (Fig. 26) if the same bowl is used again.
8. Replace and tighten drain plugs in the crankcase and filter if removed.

Fig. 22—Check The Engine Oil Level Daily





Fig. 23—Removing Engine Crankcase Drain Plug

9. Install new filter gasket, if supplied with filter. With a "spin-on" filter, apply a light film of engine oil or grease to the gasket or sealing ring (Fig. 27) before installing it. This will prevent tearing the seal as it is tightened.

10. Install new filter cartridge. Do not tighten too much as seals can be damaged. With spin-on filters, turn the filter until the seal contacts the base, then tighten no more than an extra $\frac{1}{2}$ turn (Fig. 27). This keeps from over-tightening which distorts the seal and causes leaks.

IMPORTANT: Be sure the new filter is an exact duplicate of the one recommended by the engine manufacturer.

11. If separate filter bowl is used, replace it and tighten. Do not over-tighten.

12. Fill crankcase with new oil. Use the proper amount of oil. Do not overfill. Clean tops of oil cans and use a clean funnel or spout (Fig. 28). Use the viscosity and type of oil recommended in your operator's manual.

13. Start the engine and operate it for a few minutes. This gives the oil an opportunity to coat and protect parts and fill the oil filter.

14. Check for oil leaks around the drain plug and the filter (Fig. 29). Also check the pressure gauge on control console to make certain that the oil pump is working properly.

15. Check oil level on the dipstick, after allowing engine to set for a few minutes. If oil is not to the "full" line, add more until it reaches that level. *Do not over-fill*; this can cause oil consumption and oil foaming.

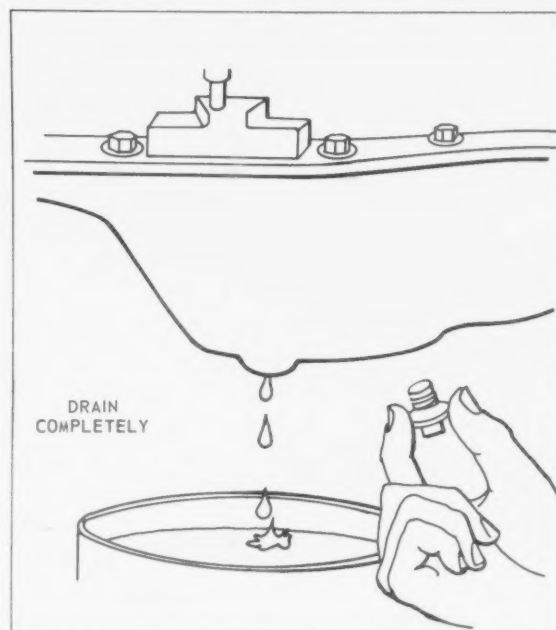
TESTING ENGINE OIL PRESSURE

The modern engine must have full oil pressure or not enough lubricating oil will reach vital engine working parts (Fig. 29).

All modern engines with pressurized lubricating systems have an oil pressure gauge on the operator's console (Fig. 30). Watch this gauge for proper oil pressure. Once the engine is started and running, this gauge should read in the normal range (or go out if it is a glowing indicator). If not, stop the engine at once and find the cause.

If engine oil pressure is too low, crankcase oil level may be down, oil may be too thin, oil pump or engine bearings may be worn, the gauge may be bad, or the pressure valve may only need adjustment.

Fig. 24—Allow Crankcase To Drain Completely



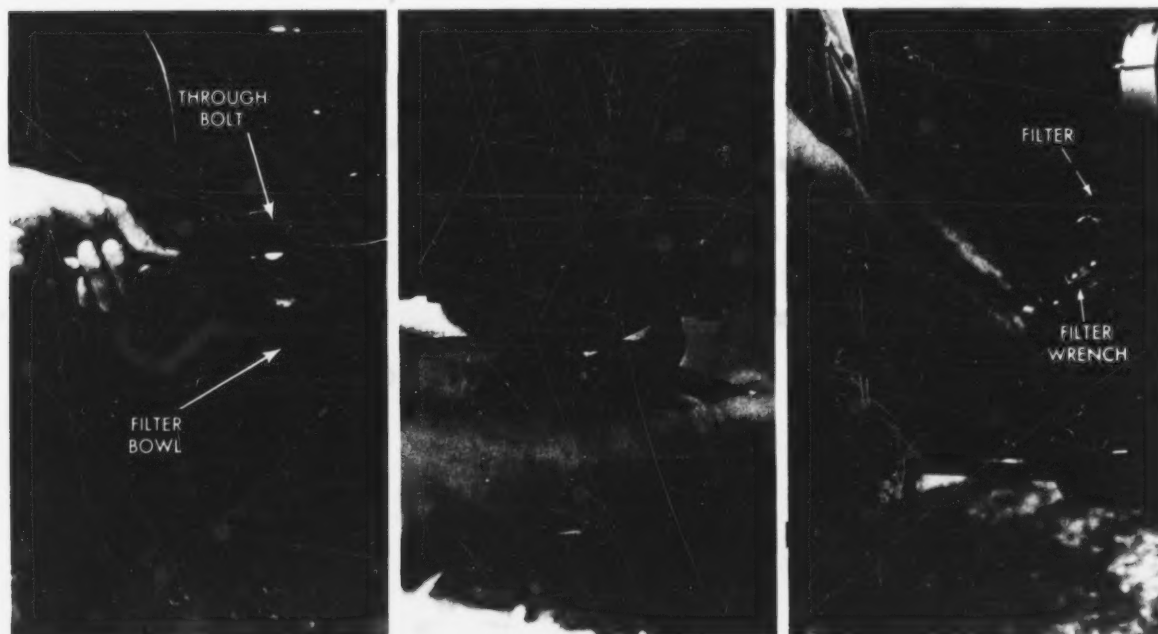


Fig. 25—Removing Three Kinds Of Engine Oil Filters

Fig. 26—Cleaning Inside Of Filter Bowl And Base



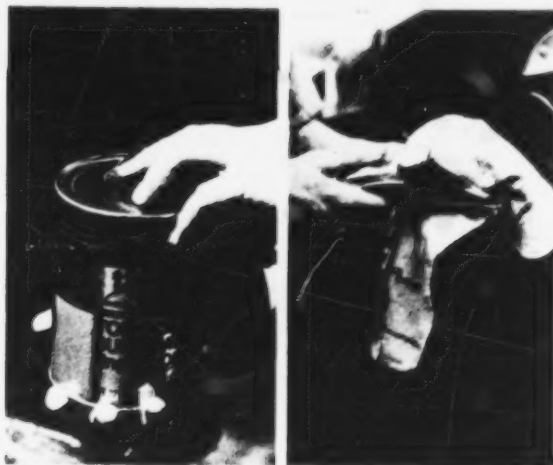


Fig. 27—Clean Oil Container And Filling Equipment

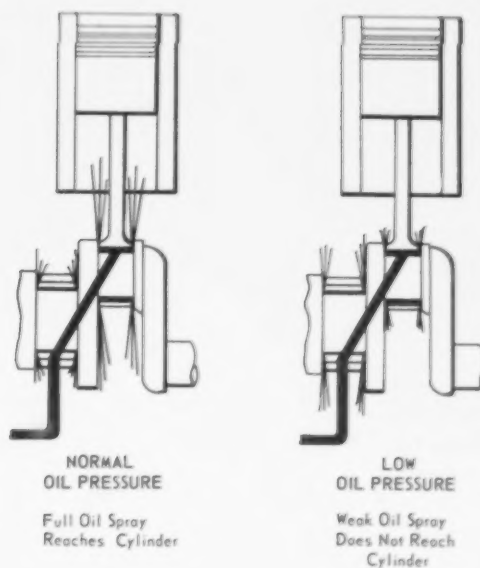


Fig. 29—Low Oil Pressure Means Lack Of Engine Lubrication

Fig. 28—Check For Oil Leaks After Installing Engine Filter



Fig. 30—Engine Oil Pressure Gauge On Operator's Console



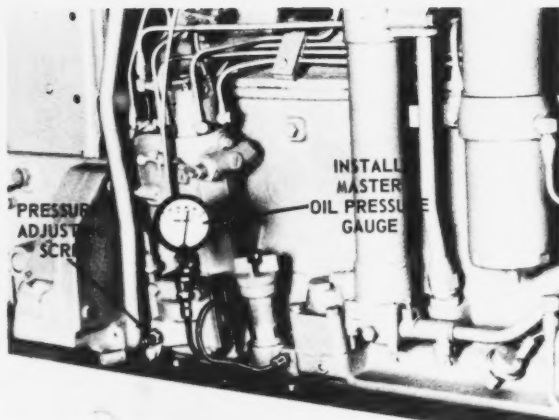


Fig. 31—Checking The Engine Oil Pressure

Too-high oil pressure is not as common, but can be caused by crankcase oil that is too heavy, a defective pressure gauge, or a stuck regulating valve or one that is out of adjustment.

Anytime the oil pressure is too high or low, stop the engine and install a master gauge to check it as follows:

HOW TO TEST ENGINE OIL PRESSURE

1. Before checking the engine oil pressure, always check the condition of the oil filter. A dirty filter will drop the pressure reading.
2. Also check the oil level in the crankcase. Low oil level may show up as low oil pressure.
3. Many engines have tapped holes in the block as oil pressure test points. On other engines, the oil pressure sending unit hole is used for testing.
4. Install a master gauge as shown in Fig. 31.
5. Start and run the engine at fast-idle speed.
6. When the engine is warmed up to operating temperature, record the pressure reading on the gauge. Compare this reading with the specifications for the engine.
7. If master gauge indicates pressure is satisfactory, but gauge on operator's console still reads high or low, replace oil pressure sensor and/or gauge which are often supplied as a single unit.
8. Adjust engine oil pressure if necessary.

Some regulating valves are adjusted by an adjusting screw (Fig. 32). Normally, turn the screw *in* to increase the spring tension and the pressure setting. Turn the screw *out* to decrease the pressure setting.

Shims and washers are used for adjusting pressure in

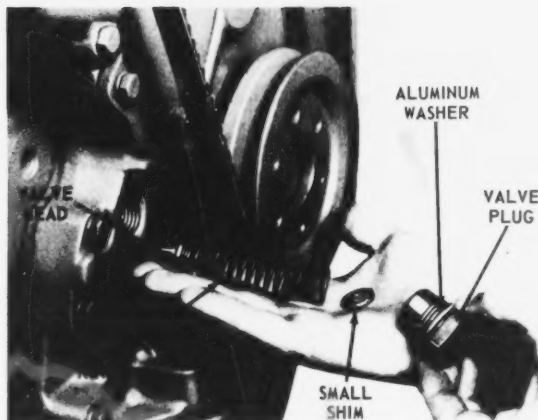


Fig. 32—Adjusting Engine Oil Pressure (Shim-Adjusted Valves)

some regulating valves (Fig. 32).

To lower pressure, shims are removed to decrease the tension of the spring and allow the valve to open at a lower setting.

Recheck pressure on master gauge. If okay, remove gauge and install plug.

If the oil pressure problem continues, have a serviceman inspect the engine.

CHAPTER QUIZ

1. What four functions must engine oil perform to keep engines running?
2. (Fill in blank.) The Society of Automotive Engineers established the SAE _____ designation which is a measure of the fluidity of an oil at a given temperature.
3. True or false? "When the crankcase oil is black, it is time for an oil change."
4. True or false? "Oil additives hardly ever wear out."
5. (Fill in blank.) Oil _____ will reduce engine life more than any other factor.
6. Name the three types of lubricating systems.
7. (Fill in blanks.) The two basic types of oil filtration systems are _____ and _____.
8. How often should the engine crankcase oil level be checked?
9. Why should an engine be warmed up before draining the oil?
10. True or false? "Tighten oil filters as tight as possible or they may leak."

5

Engine Cooling Systems



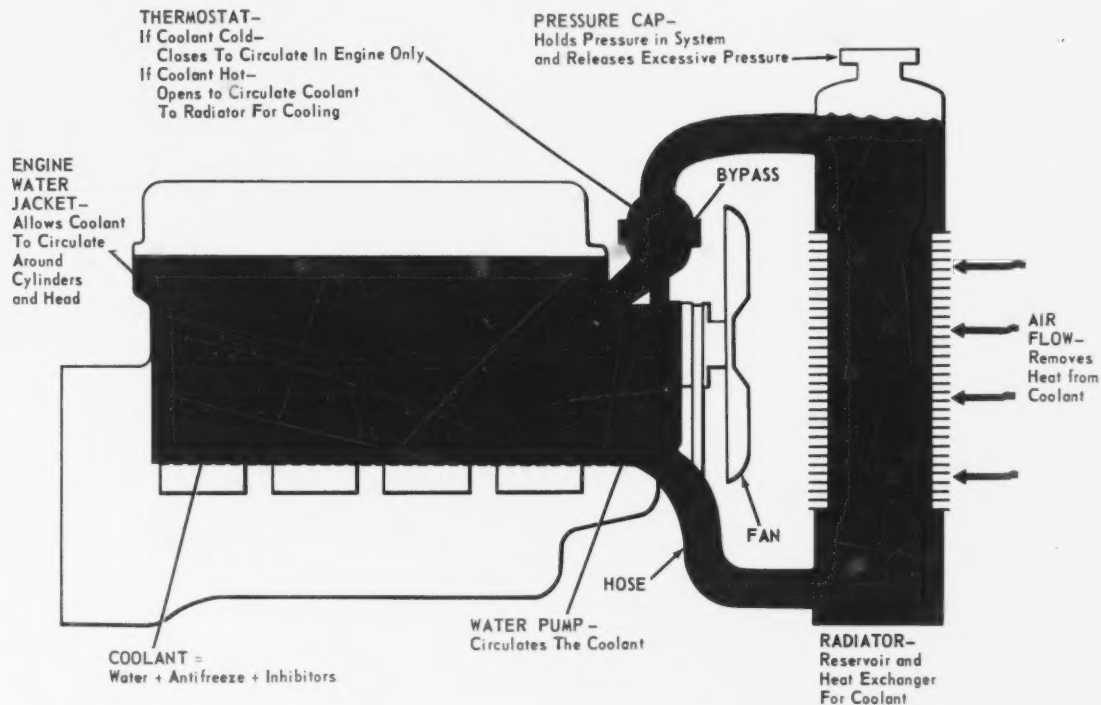


Fig. 1—Basic Engine Cooling System

INTRODUCTION

If a liquid-cooled engine were run without its coolant, the pistons and bearings would soon *weld* to their mating parts and the engine would be damaged beyond repair.

JOB OF COOLING SYSTEM

The engine cooling system does two things:

- Prevents overheating
- Regulates temperatures

OVERHEATING could "burn up" the engine parts. Some heat is necessary for combustion, but the engine generates too much. So the cooling system is designed to carry off the excess heat.

REGULATING TEMPERATURES keeps the engine at the best heat level for each operation. Just after starting, the engine must be warmed faster, while during peak operations, the engine must be cooled and kept

at a constant temperature.

PARTS OF COOLING SYSTEM

A liquid cooling system (Fig. 1) consists of the following:

- Radiator and Pressure Cap
- Fan and Fan Belt
- Coolant Pump
- Engine Coolant Jacket
- Thermostat
- Connecting Hoses
- Liquid or Coolant
- Coolant Filter-Conditioner (if used)

Now we will see how these parts function in the complete system.

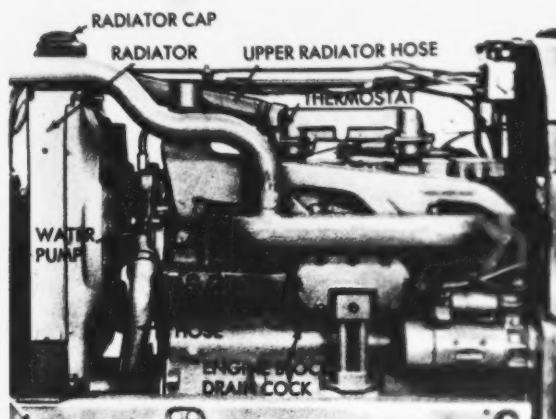


Fig. 2—Liquid Cooling System On Modern Engine

OPERATION OF COOLING SYSTEM

The **RADIATOR** is one of the major components of any liquid cooling system (Fig. 1). It is here that heat in the coolant is released to the atmosphere. The radiator also provides a reservoir for enough liquid to operate the cooling system efficiently.

Coolant from the engine enters the radiator by way of the top tank, then passes down through a series of small tubes surrounded by fins and air passages. Cooled liquid reaching the bottom tank is picked up by the water pump to repeat the complete cycle.

Fig. 3—Pressure Control Radiator Cap

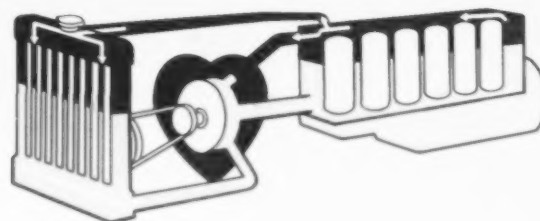
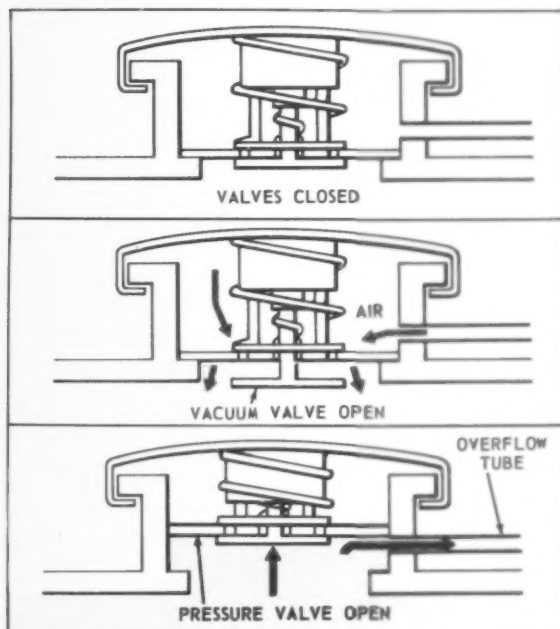


Fig. 4—Coolant Pump Is Heart Of Cooling System

The **RADIATOR CAP** (Fig. 3) provides pressure control of the cooling system. With a pressure cap, the boiling point of the coolant can be raised (a 7 psi [50 kPa] cap raises the boiling point of water from 212° to about 230°F, or approximately 100° to 110°C). This allows the engine to operate at higher temperatures for better efficiency.

A **pressure valve** (Fig. 3) in the cap permits the escape of coolant or steam when the pressure reaches a certain point.

The **vacuum valve** in the cap opens to prevent a vacuum in the cooling system when the system cools.

The **FAN** forces cooling air through the radiator core to more quickly dissipate the heat being carried by the coolant into the radiator.

The fan is generally driven by a V-belt from the engine crankshaft.

The **COOLANT PUMP** circulates the coolant through the cooling system (Fig. 4). The pump draws hot coolant from the engine block and forces it through the radiator for cooling. When the pump fails to circulate the coolant, heat is not removed from the engine and overheating will occur.

The **THERMOSTAT** provides automatic control of engine temperature at the correct level. This is necessary in order to get the best performance from an engine.

During warm-up the thermostat remains closed (Fig. 5, right). The water pump circulates the coolant through the engine coolant jacket only, by way of the bypass.

This quickly warms the engine to its operating temperature before the thermostat opens (Fig. 5, left).

When the thermostat opens (usually at 180°F to 190°F; 82° to 88°C), hot coolant flows from the engine to the radiator and back. An engine operating at a temperature lower than recommended will use more fuel, have less power, and have increased cylinder wear.

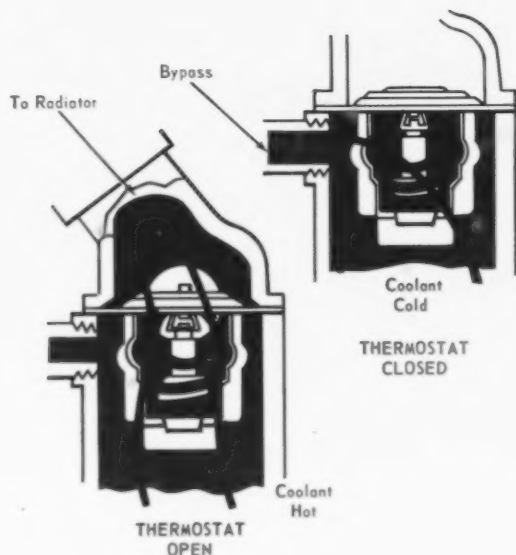


Fig. 5—Thermostat For Cooling System

The COOLING SYSTEM HOSES are flexible because they stand up under vibration better than rigid pipes.

A COOLANT FILTER-CONDITIONER (used on some engines) contains chemicals which soften the water, maintain a proper acid/alkaline condition, prevent corrosion, and suppress cavitation erosion.

The COOLANT or liquid which circulates in the system to absorb and release heat will be covered next.

SELECTING COOLANTS

You may say, "What's so difficult about selecting a coolant? Just use water in the summer and antifreeze in the winter."

Fig. 6—Selecting Coolants For The Engine

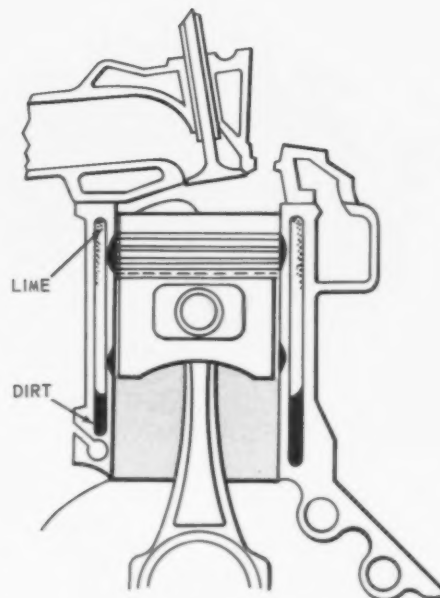
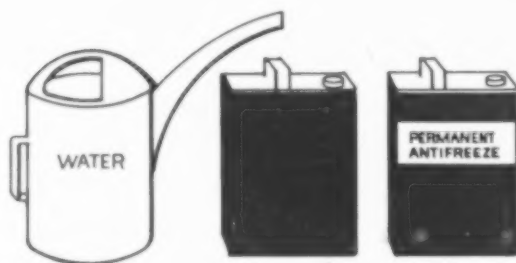


Fig. 7—Mineral Deposits From Using Water Alone As A Coolant

But if you were to maintain your cooling system in this manner, it would soon give you trouble.

WATER AS A COOLANT

Water by itself is not a satisfactory coolant. Without inhibitor additives it will rust, corrode, and leave deposits in the engine coolant jacket and cause the radiator to plug (Fig. 7). Without an antifreeze solution, it will freeze at 32°F (0°C).

The best water for coolant is clean soft water—distilled water or rain water is the best source. Most ground water is too hard and contains minerals which form scale in the engine. Artificially softened water is better, but there are still dissolved minerals in it. Even distilled water, while the purest of all, needs inhibitors.

The problem is that *all* waters tend to either corrode or form deposits. Waters that have been softened may tend to corrode metal parts, while harder tap waters tend to form deposits.

The safest rule is to add commercial **inhibitors** to the water even in summer to prevent rust, corrosion, and deposits.

Usually when the radiator becomes clogged, up to 90 percent of the material is rust (Fig. 8).

ANTIFREEZES

When freezing is expected, the cooling system must have a coolant which will not readily freeze.

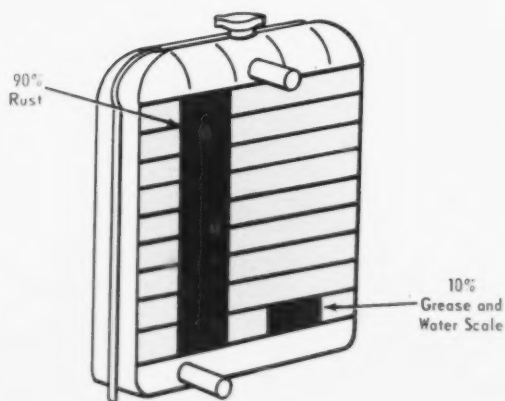


Fig. 8—Rust In Clogging Material

If the coolant freezes, it will expand and may crack the engine block or head and create leaks. It may also weaken the radiator and hoses. During operation, freezing can prevent circulation and cause the engine to run hot.

Antifreeze solutions are used in the system to prevent freezing. They must do the following to be effective:

1. Prevent freezing at lowest expected temperatures
2. Inhibit rust and corrosion of system parts
3. Be chemically stable
4. Flow readily at all temperatures
5. Conduct heat readily
6. Resist foaming

Other minor requirements of antifreezes are that they should not lower the boiling point of water too much,

not expand too much, and not have too unpleasant an odor.

Types of Antifreezes

The two types of antifreeze used in most engines today are:

- Ethylene glycol base (permanent)
- Alcohol base

Since most engines operate at temperatures above the boiling point of alcohol (Fig. 9), the permanent-type (ethylene glycol) is usually recommended.

The term "permanent antifreeze" means only that the solution will not boil away at normal engine temperatures. It does *not* mean that the good qualities of the solution never wear out. Most permanent antifreezes are recommended for only one or at most two seasons before they should be replaced.

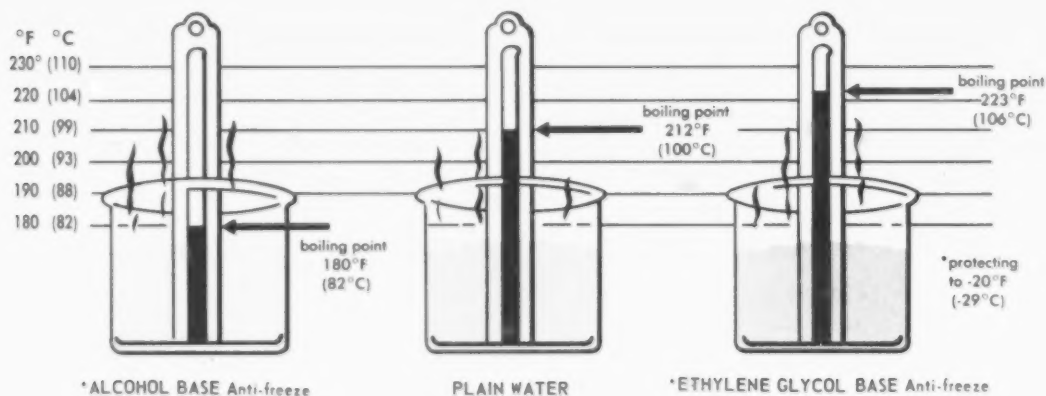
Freezing Protection For Coolant

When you add antifreeze, protect for the *lowest* expected temperatures. The map in Fig. 15 shows the lowest temperature observed in various parts of the United States during the past 50 years (from U.S. Weather Bureau records).

Check your operator's manual for the system capacity of your engine. Then use the chart in Fig. 10 to find how much full-strength "permanent" antifreeze is required to protect to the lowest expected temperature. For example, a tractor operating in Northern Illinois should be protected to approx. -25°F (-32°C). If the tractor cooling system had a 20 quart (75 liter) capacity, then 10 quarts (or 37 liters) of permanent antifreeze would be needed.

Install and maintain a 33 to 50 percent solution (0°F ; -18°C freezing protection) for corrosion protection. A 50 percent solution will provide protection to -34°F (-36°C). (A 68 percent solution will protect to about -90°F ; -68°C).

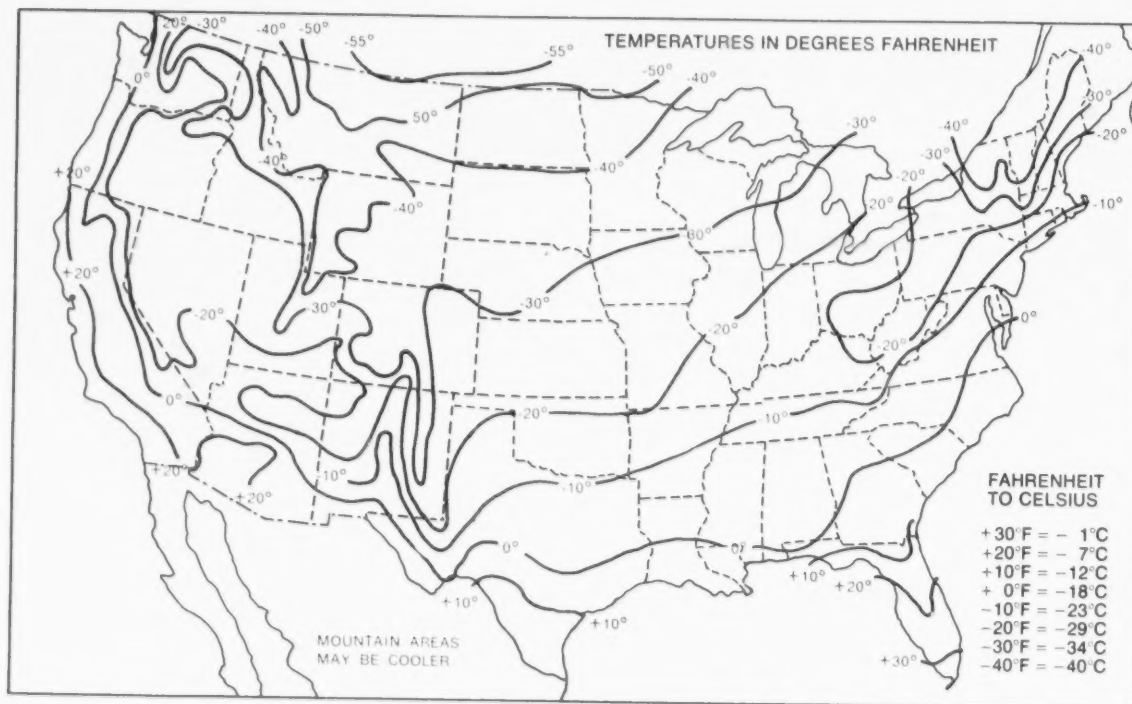
Fig. 9—Boiling Points of Antifreezes Compared to Water



FREEZING PROTECTION TABLE

Cooling System Capacity Quarts (Liters)	FULL STRENGTH "PERMANENT" ANTIFREEZE REQUIRED												
	Quarts												
	1 °F (°C)	2 °F (°C)	3 °F (°C)	4 °F (°C)	5 °F (°C)	6 °F (°C)	7 °F (°C)	8 °F (°C)	9 °F (°C)	10 °F (°C)	11 °F (°C)	12 °F (°C)	13 °F (°C)
5 (4.7)	16° (-9.0°)	-12° (-22.0°)	-62° (-52.0°)										
6 (5.7)	19° (-7.0°)	0° (-17.5°)	-34° (-36.5°)										
7 (6.6)	22° (-5.5°)	7° (-14.0°)	-17° (-27.0°)	-54° (-47.5°)									
8 (7.6)	23° (-5.0°)	11° (-12.0°)	-7° (-14.0°)	-34° (-36.5°)	-69° (-56.0°)								
9 (8.5)	24° (-4.5°)	14° (-10.0°)	0° (-17.5°)	-21° (-29.5°)	-50° (-45.5°)								
10 (9.5)	25° (-4.0°)	16° (-9.0°)	4° (-15.5°)	-12° (-24.5°)	-34° (-36.5°)	-62° (-52.0°)							
11 (10.4)	26° (-3.5°)	18° (-8.0°)	8° (-13.5°)	-6° (-21.0°)	-23° (-31.0°)	-47° (-44.0°)							
12 (11.4)	19° (-7.0°)	10° (-12.0°)	0° (-17.5°)	-15° (-26.0°)	-34° (-36.5°)	-57° (-49.5°)							
13 (12.3)		21° (-6.0°)	13° (-10.5°)	3° (-16.0°)	-9° (-23.0°)	-25° (-31.5°)	-45° (-43.0°)	66° (-55.5°)					
14 (13.2)			15° (-9.5°)	6° (-14.5°)	-5° (-20.5°)	-18° (-28.0°)	-34° (-36.5°)	54° (-47.5°)					
15 (14.2)			16° (-9.0°)	8° (-13.5°)	0° (-17.5°)	12° (-24.5°)	-26° (-32.0°)	-43° (-41.5°)	-62° (-52.0°)				
16 (15.1)			17° (-8.5°)	10° (-12.0°)	2° (-16.5°)	-8° (-22.0°)	-19° (-28.5°)	-34° (-36.5°)	-52° (-46.5°)				
17 (16.1)			18° (-8.0°)	12° (-11.0°)	5° (-15.0°)	-4° (-20.0°)	-14° (-25.5°)	-27° (-33.0°)	-42° (-41.0°)	-58° (-50.0°)			
18 (17.0)			19° (-7.0°)	14° (-10.0°)	7° (-14.0°)	0° (-17.5°)	-10° (-23.5°)	-21° (-29.5°)	-34° (-36.5°)	-50° (-45.5°)	-65° (-54.0°)		
19 (18.0)			20° (-6.5°)	15° (-9.5°)	9° (-13.0°)	2° (-16.5°)	-7° (-22.0°)	-16° (-26.5°)	-28° (-33.5°)	-42° (-41.0°)	-56° (-49.0°)		
20 (18.9)				16° (-9.0°)	10° (-12.0°)	4° (-15.5°)	-3° (-19.5°)	-12° (-24.5°)	-22° (-30.0°)	-34° (-35.5°)	-48° (-44.5°)	-62° (-52.0°)	
21 (19.9)				17° (-8.5°)	12° (-11.0°)	6° (-14.5°)	0° (-17.0°)	-9° (-23.0°)	-17° (-27.0°)	-28° (-33.5°)	-41° (-40.5°)	-54° (-47.5°)	-68° (-55.5°)
22 (20.8)				18° (-8.0°)	13° (-10.5°)	8° (-13.5°)	2° (-16.5°)	-6° (-21.0°)	-14° (-25.5°)	-23° (-31.0°)	-34° (-36.5°)	-47° (-44.0°)	-59° (-50.5°)
23 (21.8)				19° (-7.0°)	14° (-10.0°)	9° (-13.0°)	4° (-15.5°)	3° (-19.5°)	-10° (-23.5°)	-19° (-28.5°)	-29° (-34.0°)	-40° (-40.0°)	-52° (-46.5°)
24 (22.7)					15° (-9.5°)	10° (-12.0°)	5° (-15.0°)	0° (-17.0°)	-8° (-22.0°)	-15° (-26.0°)	-24° (-31.0°)	-34° (-36.5°)	-46° (-43.5°)

(NOTE: Celsius temperatures above are rounded to nearest 0.5°)



LOWEST TEMPERATURE OBSERVED IN DIFFERENT PARTS OF THE UNITED STATES
BASED ON U. S. WEATHER BUREAU RECORDS FOR 50 YEARS

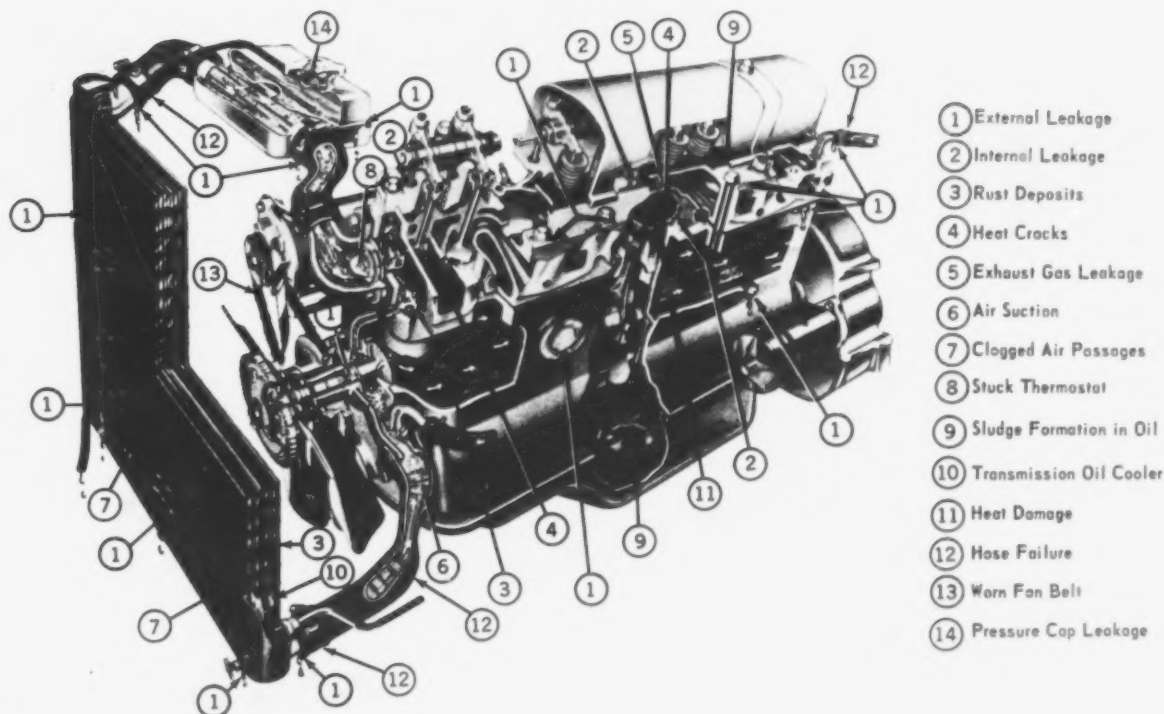


Fig. 11—Maintenance Problems Of The Engine Cooling System

Because of the nature of ethylene glycol, a greater concentration of antifreeze will actually give *less* protection. Examples of this are that an 80 percent solution will provide protection to -57°F (-50°C) and a 100 percent solution provides protection only to -9°F (-23°C).

IMPORTANCE OF SERVICE

The cooling system absorbs about $\frac{1}{3}$ of the heat energy developed by the engine fuel. Another $\frac{1}{3}$ of the heat energy is used for power, and the remaining $\frac{1}{3}$ is dissipated through exhaust gases and crankcase oil. If the cooling system fails to remove its share of the heat, the engine may be severely damaged.

In Fig. 11 you can see some of the problems of a poorly maintained cooling system. These problems not only affect the cooling system but other parts of the engine and could result in costly damage.

Fig. 10—Freezing Protection For Engine Cooling Systems in U.S.A.

Damage From Engine Too Hot

If these problems *cause the engine to run too hot*, the following damage may result:

- Burned Valves and Spark Plugs
- Scored Pistons
- Lubrication Failure
- Excessive Engine Wear
- Engine Knock, Detonation or Preignition

Damage From Engine Too Cold

If the engine runs too cold, the following may result:

- Unnecessary Wear
- Poor Fuel Economy
- Crankcase Dilution by Fuel
- Fouled Spark Plugs



Fig. 12—Checking Coolant Level

SERVICING THE COOLING SYSTEM

To maintain the engine cooling system properly, check the coolant level daily and perform other periodic maintenance as explained below.

TOOLS AND MATERIALS NEEDED

1. Commercial *flushing* compound if cooling system is in good condition.
- Commercial *cleaning* compound if there is much scale and rust present.
2. Soft water.
3. Clean container to catch drained coolant.
4. Adjustable pliers.
5. Screwdriver.
6. Wrenches (if needed, inch or metric, as required).
7. Goggles or glasses for eye protection.

SERVICES TO BE COVERED

Maintenance of the cooling system will be covered as follows:

- Checking coolant
- Preventing leaks
- Preventing corrosion
- Flushing or cleaning system
- Filling system with coolant
- Coolant pump lubrication
- Checking fan belt

Let's discuss each subject in detail.

CHECKING COOLANT

Checking Coolant Level

CAUTION: When checking the coolant level, wait until the coolant temperature has cooled well below the boiling point before removing the pressure cap (Fig. 12). Then loosen the cap only to the first stop to relieve pressure before removing the cap completely.

The coolant level should be $\frac{1}{2}$ to 2 inches (12 to 48 mm) below the neck of the radiator tank, depending on the system (Fig. 13). Follow the engine manufacturer's recommendations. *Never overfill the system.* A pressurized system needs space for heat expansion without overflowing. As the coolant expands with heat, any excess coolant will overflow and this wastes antifreeze. Continued overfilling can dilute the antifreeze concentration and there will no longer be adequate freeze protection.

Fig. 13—Proper Level Of Engine Coolant In Radiator

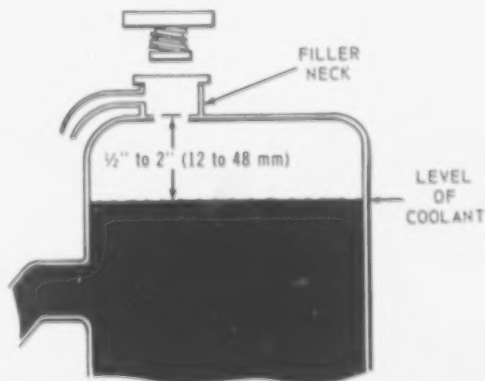




Fig. 14—Removing Trash From Radiator Or Screen

Check the radiator cap and gasket. If in doubt, replace the cap with an exact duplicate (see "Testing Radiator Cap" later in this chapter).

Check for leaks around the radiator, hoses, and hose clamps.

Remove trash from the radiator or radiator screen.

If you have water under pressure, use a hose as shown in Fig. 14. Direct the stream against the radiator from the side next to the engine.

Fig. 15—Checking Freezing Protection Using A Hydrometer



When operating in trashy conditions such as in corn harvesting, check the radiator for trash several times a day.

IMPORTANT: Never pour hot water into a cold engine or cold water into a hot engine that is not running. You may crack the head or the cylinder block. Do not operate the engine without water for even a few minutes.

Checking Antifreeze Solutions

Use a hydrometer to test the freezing protection of antifreeze solutions (Fig. 15). The hydrometer must have a thermometer and a correction table in order to check accurately the antifreeze protection.

If a simple hydrometer is used, it will give a correct reading only at one temperature—usually 60°F (15°C). This is because the density of a liquid changes with the temperature. Therefore, be sure the hydrometer has a thermometer built in. Also, never mix the two types of antifreeze (alcohol and ethylene glycol), as the hydrometer will not be accurate.

If the hydrometer shows lack of protection against freezing at the lowest expected temperature, drain some coolant and refill with fresh antifreeze. Or, drain, flush and refill the cooling system with the proper amount of antifreeze and clean, soft water. See procedure on page 81.

PREVENTING LEAKS

Leaks in the cooling system can mean a loss of valuable antifreeze. A serious leak could cause the engine to overheat and become damaged.

If antifreeze solution leaks into the engine crankcase (Fig. 16), it can dilute the oil until the engine's lubrication fails. When antifreeze or water mixes with oil, it forms sludge and gum which retard lubrication and cause sticking of valves, valve lifters or piston rings.

To prevent leakage of coolant into the crankcase, check the cylinder head joints periodically to be sure the gasket is okay and the cap screws are tightened to specifications.

Watch oil level in the crankcase. If oil level rises, either coolant or unburned fuel is entering the crankcase. Determine the problem and make corrections immediately.

Cooling system leaks can be caused by other problems: Loose cylinder head and other gasket joints, loose hose clamps, fracture of radiator solder, corroded water tubes in the radiator, and rotten hoses and gaskets.

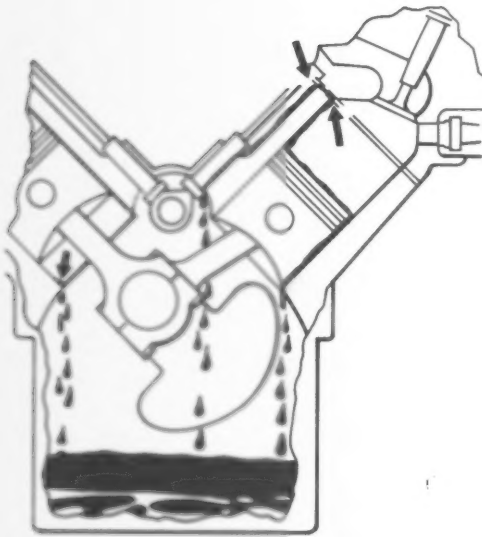


Fig. 16—Coolant Leaking Into The Crankcase Can Cause Lubrication Failure

Stop-Leak Products

To stop small leaks, at least temporarily, stop-leak compounds can sometimes be used. The main problem is that they give a sense of false security. For example, stop-leak may prevent seepage at a hose connection through the inner lining, but eventually the hose will rot and burst, losing coolant and overheating the engine.

Also, stop-leak compounds *will not* correct a leaking cylinder head gasket because of the heat and pressures.

Stop-leak compounds can also lead to radiator clogging if water tubes already contain deposits which act as a strainer. If coolant level gets too low, some stop-leak ingredients may harden in the upper radiator and block it.

However, stop-leak compounds are recommended for preventive maintenance in some engines.

Before using a stop-leak, check your operator's manual. Some manufacturers do not recommend them. If used, the compound must be compatible with the antifreeze and the inhibitors, and it must be added correctly and in the right quantity.

NOTE: Do not use coolant system stop-leak additives if the engine is equipped with a coolant filter-conditioner. The stop-leak compound will plug the filter.

NOTE: Some antifreezes now contain stop-leak additives. If this type of antifreeze is approved by the engine maker, no further stop-leak compound is needed in the system.

Air Leaks Into Cooling System

Air mixing with the coolant in the system speeds rusting and corrosion. It may also cause foaming, overheating, and overflow loss of coolant.

Air leaks into the coolant may be caused by:

- Leak in the system
- Turbulence in top radiator tank
- Too-low coolant level

Exhaust Gas Leaks Into System

A cracked head or a loose cylinder head joint allows hot exhaust gas to be blown into the cooling system under combustion pressures, even though the joint may be tight enough to keep liquid from leaking into the cylinder.

The cylinder head gasket itself may be burned and corroded by escaping exhaust gases.

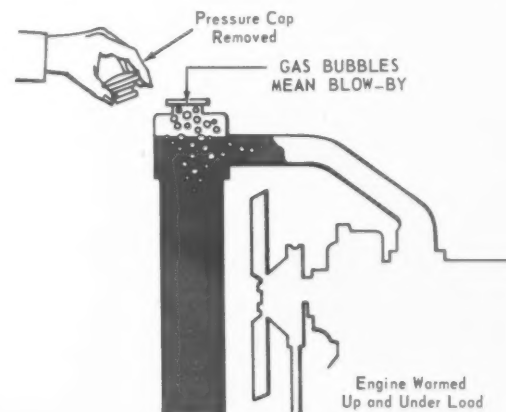
Exhaust gases dissolved in coolant destroy the inhibitors and form acids which cause corrosion, rust, clogging, and damage to rubber parts.

Excess pressure may also force coolant out the overflow pipe.

Either bubbles or an oil film present in the coolant is a sign of blow-by in the engine cylinders (Fig. 17).

NOTE: Make this test quickly, before boiling starts, since steam bubbles give misleading results.

Fig. 17—Checking For Exhaust Gas Leakage That May Indicate Blow-By



PREVENTING CORROSION AND DEPOSITS

Three types of corrosion can attack the parts of the cooling system:

- Chemical corrosion
- Electrolytic corrosion
- Erosive corrosion

CHEMICAL CORROSION is a direct chemical reaction between the coolant and the metal parts of the system. This may be caused by acids in the coolant or various oxidizing agents. An example is the formation of rust on iron parts by the water and oxygen reacting with the metal.

ELECTROLYTIC CORROSION is a reaction between two different metals joined together, in contact with a solution which conducts electricity. This action is the same as that of a dry-cell battery which produces current by converting a metal into salt. When selecting an antifreeze, be sure that it is not a good conductor, such as a salt solution.

EROSIVE CORROSION is the mechanical abrasion from particles such as rust, scale, and sand as they circulate rapidly through the system with the coolant.

The result of corrosion on metal surfaces is that heat transfer is reduced.

Good antifreeze solutions already contain rust and corrosion inhibitors. However, these inhibitors "wear out" with use. This is one reason why even permanent antifreezes are recommended for only one or two seasons in a system.

Water solutions will corrode the cooling system metals unless they are protected by inhibitors added to the water during summer operation. However, summer coolant additives should not be used in engines equipped with coolant filter-conditioners. *Permanent-type anti-freeze without stop-leak additives should be used all year in these engines.*

Preventing Cooling System Deposits

Lime and mineral deposits can be reduced by using soft water—distilled water or rain water is best.

Mineral deposits form rapidly at hot spots in the engine (see Fig. 7).

Because heat transfer is reduced, deposits can lead to overheating, knocks, and eventually engine damage.

Using Coolant Filter-Conditioners

Coolant filter conditioners (Fig. 18) soften water and remove dirt. The filter-conditioner may be the spin-on type as in Fig. 18. To change the filter, unscrew the canister from the engine and discard it. Install a new filter as a replacement.

Another type of filter-conditioner contains a replaceable filter element with a sump at the bottom where dirt settles after it collects in the filter. The sump can be drained periodically to remove accumulated dirt and sediment.

The spin-on type filter contains two elements. The outer paper element filters out rust, scale, or dirt particles in the coolant. The inner element releases chemicals into the coolant to soften the water, maintain a proper acid/alkaline condition, prevent corrosion, and suppress cavitation erosion.



Fig. 18—Coolant Filter-Conditioner Softens And Cleans Coolant

The chemicals released into the coolant by the inner element forms a protective film on the surface of the cylinder liner. The film acts as a barrier against collapsing vapor bubbles and reduces the quantity of bubbles formed.

FLUSHING OR CLEANING THE SYSTEM

Always flush the system before installing antifreeze. Rust and other deposits in the system can shorten inhibitor life (and also reduce cooling efficiency). When draining the system, if the coolant contains rust and scale, *clean the system with an acid-base cleaner.* Be sure to follow the manufacturer's instructions.

It is also important to follow the engine maker's instructions when flushing or cleaning their system. For example, some alkaline cleaners can corrode aluminum engines or radiators.

For heavy deposits in the system, more drastic cleaning with an acid-base cleaner may be needed. Allow the solution to remain in the system for two to three hours at operating temperatures and then drain. To neutralize the acid, flush the system with water and lye solution. After running the engine for a while, drain the system and *flush it again with clear water to remove all traces of the lye water. This is a very important step.*

In severe cases, the radiator must be removed and boiled in a tank cleaner. This is normally done in a commercial radiator shop.

Flushing The System

Incomplete flushing, such as hosing out the radiator, closes the thermostat and prevents thorough flushing of the engine coolant jacket.

For complete flushing, take the following steps:

1. Drain old coolant from the system.
2. Fill the system completely with fresh water.
3. Run the engine long enough to open the thermostat (or remove the thermostat).
4. Open all drain plugs to again drain the system completely. (Most systems have at least two drains. See Fig. 19). Some also have a drain at the engine oil cooler (if equipped). Unless all drains are opened, some coolant will be left in the system.

Clean out the radiator overflow tube and remove insects and dirt from radiator air passages, radiator grille and screens.

Also check the thermostat, radiator pressure cap, and the cap seat for dirt or corrosion.

5. Replace coolant filter-conditioner element (if used) with new element recommended by engine manufacturer.

FILLING SYSTEM WITH ANTIFREEZE

When freezing weather is expected, drain the engine completely or add an antifreeze solution to the cooling system. Normally, flush out the cooling system before adding antifreeze.

Some cooling systems must have antifreeze added instead of being drained to protect the engine from freezing. This is because the cab heater does not drain completely when the cooling system is drained. Draining the system in cold weather could result in damage to heater parts.

Most new engines are designed to use permanent-type antifreeze in the cooling system during the whole year. In this case, follow the manufacturer's instructions. There are also a few engines which have sealed cooling systems with undiluted antifreeze as coolant, but these are not common.

NOTE: Engines protected with alcohol-base antifreeze should be drained after freezing weather is past, and refilled with clean soft water and coolant conditioner.

When filling the system, use a recognized brand of new antifreeze, containing a rust inhibitor, and clean soft water. (See Fig. 10 for instructions on freezing protection.)

After adding antifreeze, run the engine for a few minutes until it reaches normal operating temperature. This will allow the thermostat to open and will assure that the solution has circulated through the entire system for full protection against freezing.

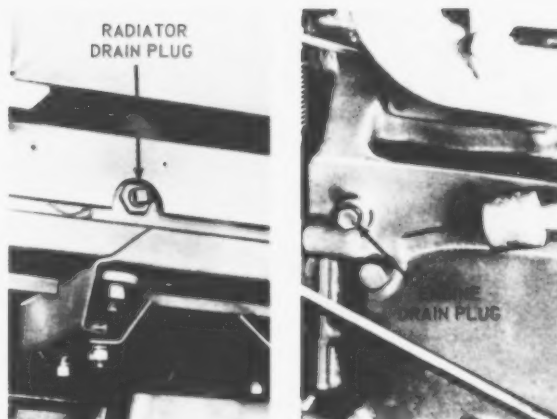


Fig. 19—Cooling System Usually Has At Least Two Drains

Recheck the cooling system for leaks and to be sure it is filled to the proper level.

COOLANT PUMP LUBRICATION

In most engines, the water pump is driven by the same shaft as the cooling fan. Usually, the shaft bearings are factory-lubricated and sealed and require no further lubrication. However, some older fan and pump units must be lubricated periodically through a grease fitting (often with a special grease). Here it is important that coolant does not leak into the bearings (Fig. 20).

Other pumps are lubricated by additives in the coolant. For this reason, most permanent antifreezes already contain a water pump lubricant; so do most inhibitors that are used with plain water. In this case, it is doubly important to *change the coolant or add inhibitors at regular intervals*. Check the operator's manual for the exact intervals and procedures as well as the label on the additives used.

Fig. 20—Coolant Pump With Corroded Bearing And Shaft



CHECKING FAN BELT

The fan belt should be neither too tight nor too loose.

Too tight a belt puts an extra load on the fan bearings and shortens the life of the bearings as well as the belt.

Too loose a belt allows slippage and lowers the fan speed, causes excessive belt wear and leads to overheating of the cooling system.

The condition of the fan belt and its tension should be checked periodically. Adjust fan belt tension as specified by the manufacturer (Fig. 21).

TESTING OF COOLING SYSTEM

In addition to regular maintenance, several tests will tell you the condition of the cooling system. These are:

- Testing system pressure
- Testing radiator cap
- Testing thermostat

Make these tests whenever the condition of the system components is in doubt. If the tests show major troubles, have the faulty parts replaced.

Fig. 21—Checking Fan Belt Tension



TESTING SYSTEM PRESSURE

Because most modern cooling systems are pressurized, all of the components must be tight and in good condition before the system can operate properly.

Overheating and loss of coolant will result unless pressure in the system is maintained.

Test the pressure in the entire cooling system as follows:

Install a *pressure tester* on the radiator according to the manufacturer's instructions (Fig. 22). *Avoid applying too much pressure.*

With the tester installed, carefully inspect the radiator, water pump, hoses, drain cocks and cylinder block for leakage.

Mark all leaks plainly to help locate them when repairs are made by a serviceman.

TESTING RADIATOR CAP

The pressure cap is vital to correct pressure build-up in the cooling system.

Use a reliable tester to test the radiator cap (Fig. 23). The pressure valve should open at a certain pressure (see engine technical manual for specifications).

If the pressure valve does not open as specified or leaks before reaching opening pressure, replace the gasket or the whole cap as necessary.

Be sure that both the cap and radiator are free from leaks.

Fig. 22—Testing the Cooling System Pressure





Fig. 23—Testing The Radiator Cap

TESTING OF THERMOSTAT

The thermostat must work properly to control the engine temperature at its best level.

Test the thermostat as follows:

1. Suspend the thermostat and a thermometer in a container of water (Fig. 24). Do not let them rest against the sides or bottom.
2. Heat and stir the water.
3. The thermostat should begin to open at the temperature stamped on it, plus or minus 10°F (5°C). It should be fully open (approximately 1/4-inch; 6 mm) at 22°F (12°C) above the specified temperature.
4. Remove thermostat and observe its closing action.
5. If the thermostat is defective, discard it.
6. Be sure to replace with an exact duplicate of the original thermostat. Notice the temperature stamped on it.

IMPORTANT: *Never operate the engine without a thermostat.*

A thermostat tester can also be used to test the thermostat, if available.

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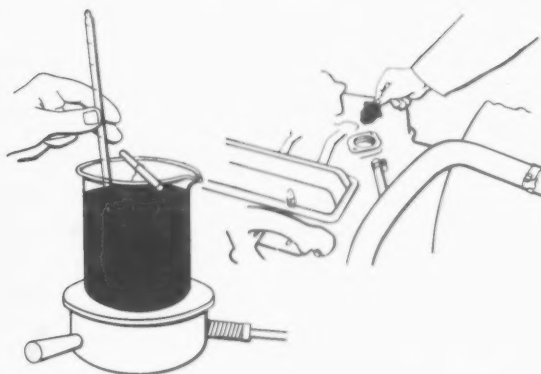


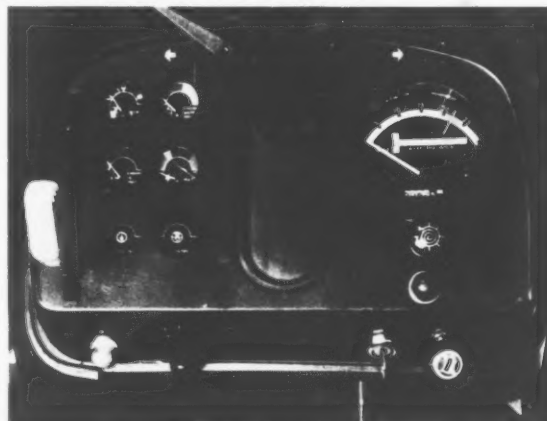
Fig. 24—Testing The Thermostat

WATCHING THE COOLANT TEMPERATURE GAUGE

All modern engines have a coolant temperature gauge to tell the operator if the engine is operating at a normal temperature (Fig. 25). Watch this gauge during operation. Once the engine is warmed up, the needle should stay in the "normal" range. If the needle goes over into the red "warning" zone, stop the engine at once. Allow engine and radiator to cool and then check for low coolant level or other causes.

Other machines may have an indicator light which glows red when the engine is too hot.

Fig. 25—Engine Coolant Temperature Gauge



NEVER STOP A HOT ENGINE

When an engine has been working hard, the pistons, turbocharger, and other parts are very hot and should be allowed to cool gradually to prevent seizing and permanent damage.

Allow a hot engine to idle for a few minutes before shutting it down.

This will prevent the engine from running after the ignition is turned off. Above all, it will keep the hot pistons and other parts from stewing and cooking in their own oil films, producing deposits. Another problem is that a red-hot valve, open when the engine stops, may warp and later burn.

NOTE: If overheating is accompanied by an indication of low oil pressure (signal light or gauge reading) stop the engine at once. Running the engine without enough oil could cause more damage than stopping a hot engine.

CHAPTER QUIZ

1. What are the two functions of the cooling system?
2. Why isn't water by itself a satisfactory coolant?
3. Which two of the following is best for a cooling system? A. Tap water B. Well water C. Distilled water D. Rain water
4. When a radiator becomes plugged, what is the major cause?
5. A 50 percent solution of antifreeze will protect against freezing to:
A. 0°F (—18°C) B. —15°F (—26°C) C. —34°F (—37°C).
6. The cooling system absorbs (1/4-1/3-1/2) of the heat energy developed by the engine fuel.
7. True or false? "The thermostat keeps the engine from overheating."
8. True or false? "It is all right to remove the radiator cap when the coolant is hot if the cap is removed slowly."
9. Never pour _____ water into a cold engine or _____ water into a hot engine.
10. (Fill in the blank.) "Either bubbles or an oil film present in the coolant is a sign of _____ in the engine cylinders."

6

**Engine
Electrical
Systems**

JOHN DEERE



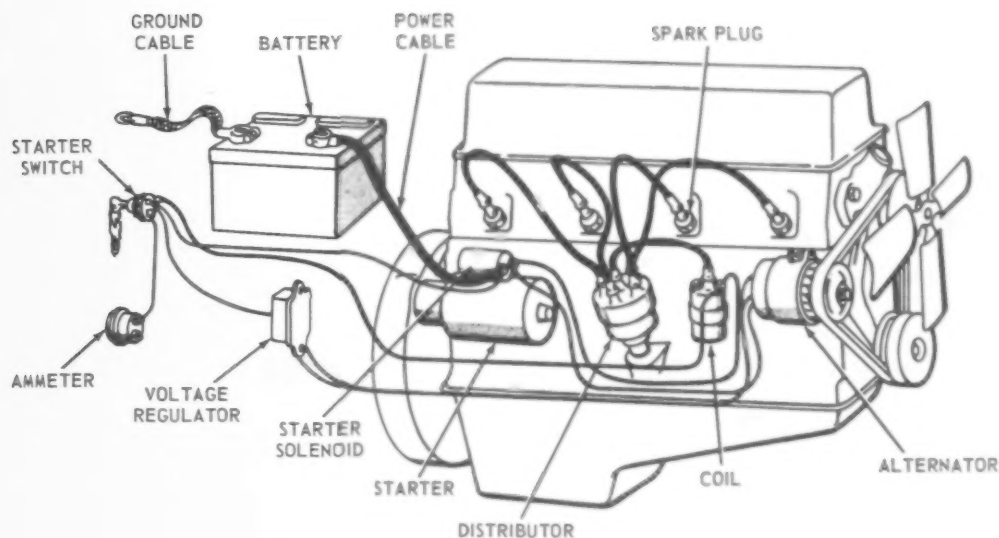


Fig. 1—Engine Electrical Systems and Components (Spark-Ignition Engine Shown)

INTRODUCTION

If the engine is hard to start or lacks good performance, it could be caused by the engine *electrical systems*. Poor maintenance of the engine's starting, charging and ignition circuits is one of the chief causes of these problems.

Engine electrical systems and components are shown in Fig. 1. The charging circuit is shown in blue, while the ignition circuit is shown in red.

For the engine to run properly, the following conditions must be present:

1. The **battery** must be fully charged to provide enough power to start the engine.
2. The **alternator** (or generator) must be able to recharge the battery when needed.
3. The **starter** must crank the engine fast enough to start the engine.
4. The **coil** must provide electrical energy to the spark plugs for igniting the fuel-air mixture.
5. The **distributor** must direct the electric current to the proper spark plug at the right moment.
6. The **spark plugs** must be clean and gapped correctly to deliver sufficient spark to ignite the fuel properly.
7. All electrical **wires and connections** must be clean and secure.

IMPORTANCE OF SERVICE

As with all preventive maintenance, the purpose is to prevent costly operation and damage to the machine. Keeping your engine's electrical systems properly serviced is just as important as any other maintenance job.

Listed below are some of the components which require attention and the results of not servicing them as recommended:

The **battery** must be kept fully charged and filled with water. It must also be kept clean. Failure to maintain the battery properly can result in brief battery life. The battery can become shorted out and lose its charge.

The **alternator** or **generator** requires periodic inspection of its brushes to insure that sufficient charge is being put back into the battery.

The **starter** brushes must also be inspected regularly to insure that the starter is not draining excessive current from the starting circuit (caused by excessive cranking). The engine will be difficult to start with too little electrical power. Also, the starter must be checked for signs of overheating.

The **distributor** must be timed correctly to direct current to the spark plugs at the proper moment for good combustion. If the timing is late, extremely hot exhaust gases are created which can warp or burn the valves. If the timing is early, power is wasted and severe "knock" (pre-ignition) can damage the pistons, valves and bearings. Also, poor timing increases fuel consumption.

The breaker points and condenser must be maintained for good current delivery to the spark plugs.

The **spark plugs** must be clean and gapped correctly to provide sufficient spark to ignite the fuel properly. If the plugs are oil fouled or have deposits on them, the plug will not fire with a good spark and the fuel will not burn completely. Loss of power and fuel economy will result. The spark plug **wiring** must also be in good condition—clean, free of cracks and shorts.

OPERATION OF ELECTRICAL SYSTEMS

The complete engine electrical system consists of three circuits:

- Charging Circuit
- Starting Circuit
- Ignition Circuit

Let's look at these circuits briefly.

CHARGING CIRCUIT

The charging circuit includes:

- Battery
- Voltage Regulator
- Alternator (or Generator)

The charging circuit does two jobs:

1. Recharges the battery
2. Generates current during operation

Types of Charging Circuits

There are two kinds of charging circuits:

- A.C. Charging Circuits (Use Alternators)
- D.C. Charging Circuits (Use Generators)

Both circuits generate an alternating current (a.c.). The difference is in the way they rectify the a.c. current to direct current (d.c.) for use by the engine.

A.C. CHARGING CIRCUITS have an *alternator* and a *regulator* (Fig. 2).

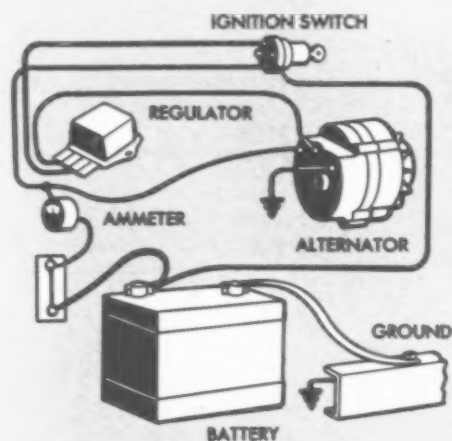
The *alternator* is really an a.c. generator. Like the generator, it produces a.c. current but rectifies it electronically using diodes. Alternators are generally more compact than generators of equal output, and supply a higher current output at low engine speeds. They have replaced generators on most modern engines.

The *regulator* in a.c. charging circuits limits the alternator voltage to a safe, preset value. Transistorized models are used in many of the modern circuits.

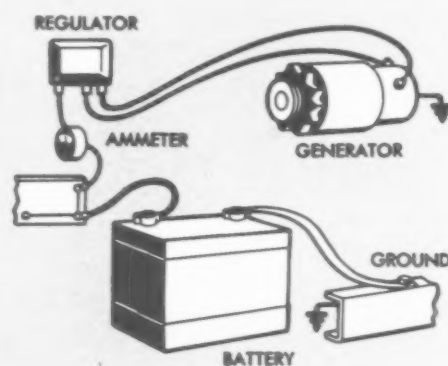
D.C. CHARGING CIRCUITS have a *generator* and a *regulator* (Fig. 2).

The *generator* supplies the electrical power and rectifies its current mechanically by using a commutator and brushes.

Fig. 2—Two Types of Charging Circuits



A-C CHARGING CIRCUIT



D-C CHARGING CIRCUIT

The *regulator* has three jobs: (1) opens and closes the charging circuit; (2) prevents overcharging of the battery; (3) limits the generator's output to safe rates so as not to damage the electrical system.

Operation of Charging Circuit

All charging circuits operate in three stages:

- During starting—battery supplies all load current
- During peak operation—battery helps alternator (or generator) supply load current
- During normal operation—alternator (or generator) supplies all current and recharges battery

In both charging circuits, the *battery* starts the circuit when it supplies the spark to start the engine. The engine then drives the alternator (or generator) which produces current to take over the operation of the ignition, lights and accessory loads in the whole system.

The battery also helps out during peak operation when the electrical loads are too much for the alternator (or generator).

But once the engine is started, the alternator (or generator) is the "workhorse" which produces current for the ignition and accessory circuits.

The alternator (or generator) supplies this current as long as the engine is speeded up. When the engine slows down or stops, the battery takes over part or all of the load.

Operation of the charging circuit during the three stages is illustrated in Fig. 3.

The top illustration shows operation while starting the engine when the battery must supply the current.

The middle diagram shows what happens during peak electrical loads when the battery only helps the alternator (or generator).

The lower diagram shows the system during normal operation when the alternator (or generator) supplies all power for loads and also recharges the battery.

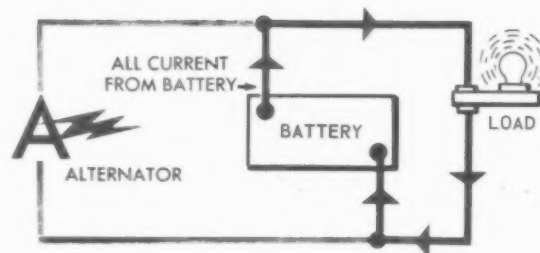
Detailed operation and maintenance will be covered later in this chapter.

STARTING CIRCUIT

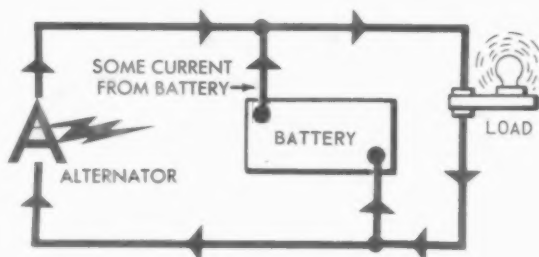
The starting circuit (Fig. 4) converts electrical energy from the battery into mechanical energy at the starting motor to crank the engine.

A basic starting circuit has four parts:

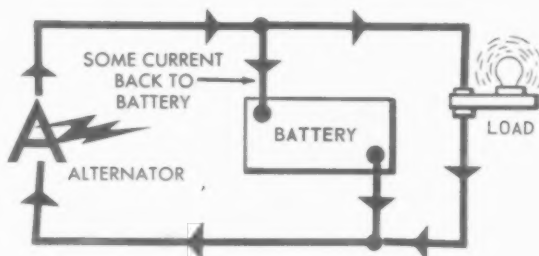
1. The **BATTERY** supplies energy for the circuit.
2. The **STARTER SWITCH** activates the circuit.
3. The **MOTOR SWITCH** (solenoid) engages the starting motor drive with the engine flywheel.
4. The **STARTING MOTOR** drives the flywheel to crank the engine.



BATTERY SUPPLYING
LOAD CURRENT



ALTERNATOR AND BATTERY
SUPPLYING LOAD CURRENT



ALTERNATOR SUPPLYING LOAD
CURRENT AND CHARGING BATTERY

Fig. 3—Charging Circuit in Operation—Three Stages
(Alternator or Generator)

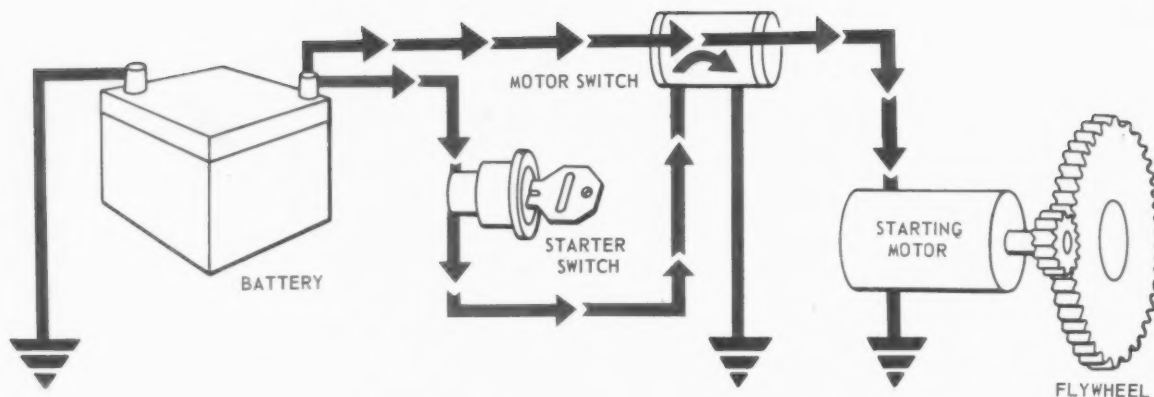


Fig. 4—Basic Starting Circuit

Operation of Starting Circuit

The starting circuit is shown in operation in Figs. 5, 6, and 7.

When the starter switch is activated by the operator (Fig. 5), a small amount of electrical energy flows from the battery to the solenoid and back to the ground circuit.

As the solenoid gets this power from the battery, it moves the solenoid plunger and engages the pinion with the flywheel (Fig. 6). The plunger also closes the switch inside the solenoid between the battery and starting motor, completing the circuit and allowing a large amount of electrical energy to flow into the starting motor.

The starting motor takes the electrical energy from the battery and converts it into rotary mechanical energy to crank the engine (Fig. 7).

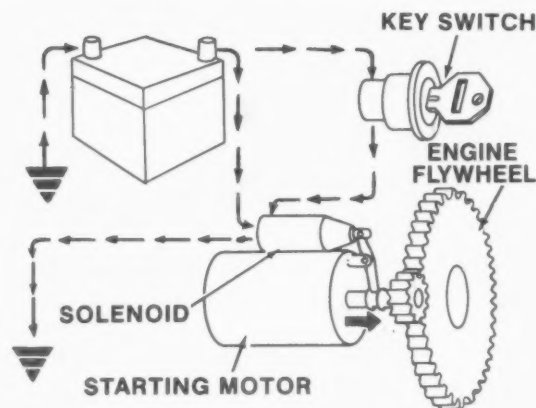


Fig. 6—Starting Circuit In Operation: (2) Starting Motor Engages Flywheel

Fig. 5—Starting Circuit In Operation: (1) As The Starter Switch Is Activated

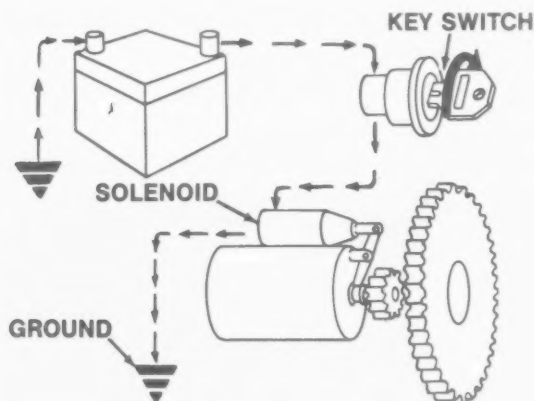
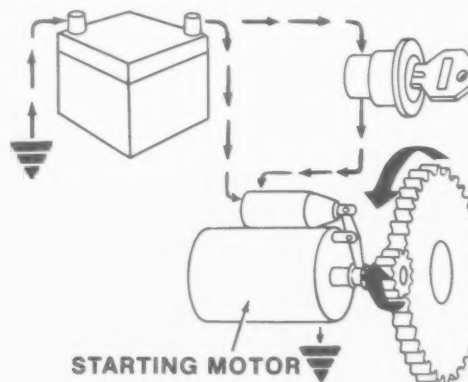


Fig. 7—Starting Circuit In Operation: (3) Starting Motor Cranks Engine



But remember that the battery is the only source of power for starting the engine.

In this typical system, we have used a solenoid switch as an example. Motors can also use other types of switches, such as manual or magnetic.

IGNITION CIRCUIT (Spark-Ignition Engines)

The ignition circuit creates the spark which ignites fuel-air mixture to power gasoline or LP-Gas engines.

To do this, the ignition circuit must:

- (1) Step up low voltage to high voltage surges
- (2) Time these surges to the engine cycle

The ignition circuit (Fig. 8) has these parts:

- Ignition Coil
- Condenser
- Distributor
- Spark Plugs
- Ignition Switch

The COIL transforms the low voltage from the battery to a high voltage for producing a spark.

The CONDENSER aids in collapsing the magnetic field in the coil to produce a high voltage. In doing this it also protects the distributor points against arcing.

The DISTRIBUTOR does three things: 1) Opens and closes the primary circuit, causing the coil to produce high voltage surges. 2) Times these surges to engine rotation, and 3) Directs each high-voltage surge to the proper spark plug.

The SPARK PLUGS ignite the fuel-air mixture within each cylinder of the engine.

The battery is the initial power source for the voltage in the ignition circuit, while the IGNITION SWITCH turns on the circuit when it cranks the engine.

Operation Of Ignition Circuit

The ignition circuit must take low voltage from the battery and create high voltage to fire the spark plugs. It must do this very accurately and very rapidly—100 or more times per second. This is why maintenance is so important.

The PRIMARY CIRCUIT is the path for low-voltage current from the power source. Note the primary circuit in Figure 8 is shown in red. It includes these parts:

- 1) Ignition Switch
- 2) Coil Primary Winding
- 3) Distributor Contact Points
- 4) Condenser

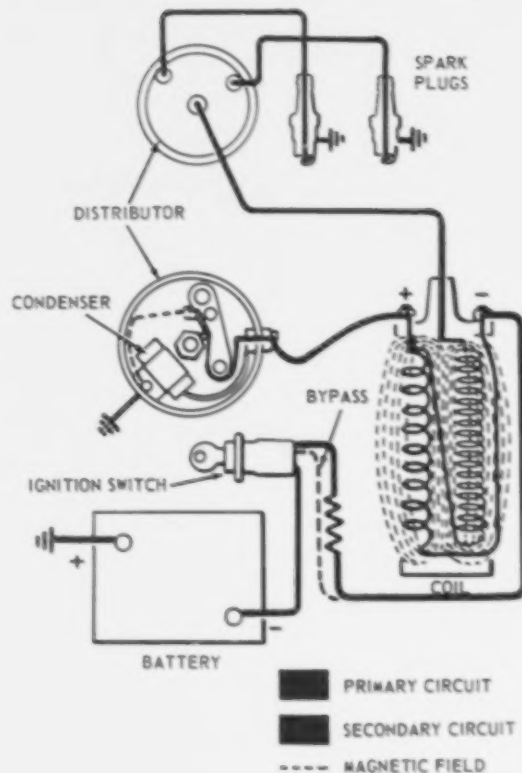


Fig. 8—Ignition Circuit (Spark-Ignition Engines)

The SECONDARY CIRCUIT is the high-voltage path for current stepped up by the coil. Note this circuit in Figure 8 is shown in blue. It includes these parts:

- 1) Coil Secondary Winding
- 2) Distributor Rotor
- 3) Distributor Cap
- 4) Spark Plug Wires
- 5) Spark Plugs

Now let's take these circuits and see how they work.

To simplify, let's divide the operation into two parts—before the distributor points open and after they open.

OPERATION BEFORE THE DISTRIBUTOR POINTS OPEN

Before the engine is started, the distributor points are normally closed (Fig. 9).

When the ignition switch is turned on, current flows from the battery into the primary windings of the coil

as shown in red. This current creates a magnetic field around the winding.

From the primary winding, the current—at low voltage—simply travels through the closed distributor points and back to ground. This is why the battery can be completely discharged if the switch is left on when the engine is not running.

OPERATION AFTER THE DISTRIBUTOR POINTS OPEN

As the engine rotates in starting, it drives the distributor shaft and the breaker cam.

When the breaker cam opens the distributor points, the second phase of ignition begins (Fig. 10).

As the points open, they open the primary circuit and divert the flow of current to the condenser, which stops flow in the primary circuit.

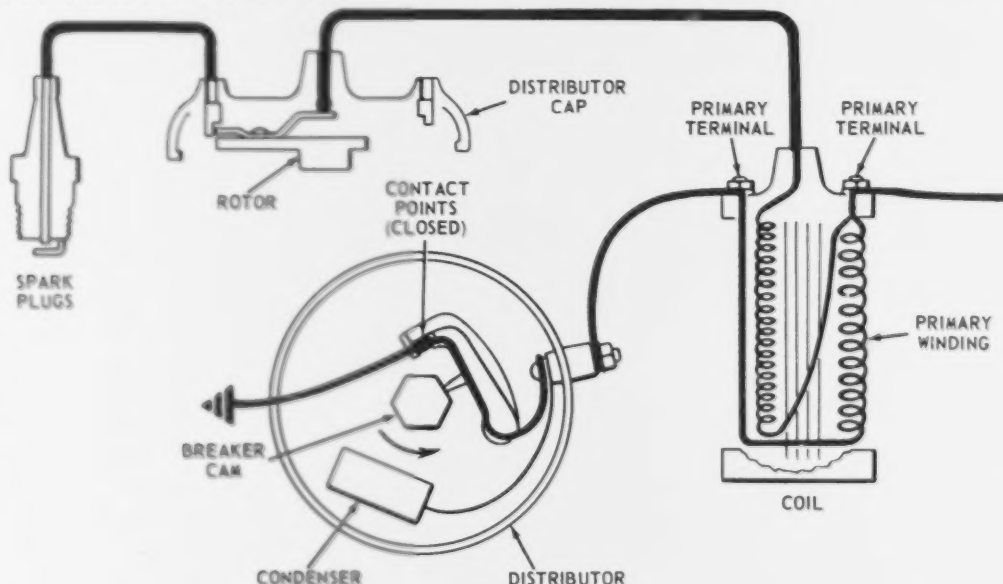
Stopping this flow causes the magnetic field around the primary winding to collapse very quickly.

This collapse induces a voltage in the primary winding which causes current to flow. The current in the primary circuit is absorbed by the condenser thus giving the current a place to flow rather than arc the breaker points.

In this case, the collapsing field further collapses across the secondary winding and induces voltage in it also.

But because the secondary is a much "stronger" winding (has more turns in proportion to the primary winding), a higher voltage is induced there—or 4,000 to 20,000 volts.

Fig. 9—Operation Before the Distributor Points Open



This surge of high voltage "pushes" current through the secondary winding and the high-tension terminal into the distributor cap as shown in red in Fig. 10.

The rotor inside the distributor cap turns to a spark plug terminal, directing the voltage "surge" to the correct plug through insulated cables.

At the spark plug, current flows down the center electrode, jumps the gap, and creates the spark.

This whole cycle happens from 50-150 times a second, depending on the speed of the engine.

NOTE: In a "bypass" ignition system (shown in Fig. 8), there are two primary leads from switch to coil. When the switch is turned to start, full battery voltage flows through the dotted red line, resulting in a hotter spark for first ignition. When the ignition switch is released, primary current flows through the solid line and resistor to the coil. In a 12-volt system, the resistor reduces voltage by half and allows use of a 6-volt coil. This gives longer life to the distributor points and aids in faster starting.

This completes the basic operation of electrical circuits. Now we will cover maintenance for each component.

ELECTRONIC IGNITION CIRCUITS

The components of an electronic ignition system are much the same as the mechanical system just described. The main difference is the electronic ignition uses a solid state ignition control unit with a reluctor and sensor to time the spark delivery eliminating the breaker points and condenser arrangement.

There really isn't much maintenance on electronic ignition systems except keeping connections clean and tight and setting the air gap between the sensor and reluctor (more on this later p. 113).

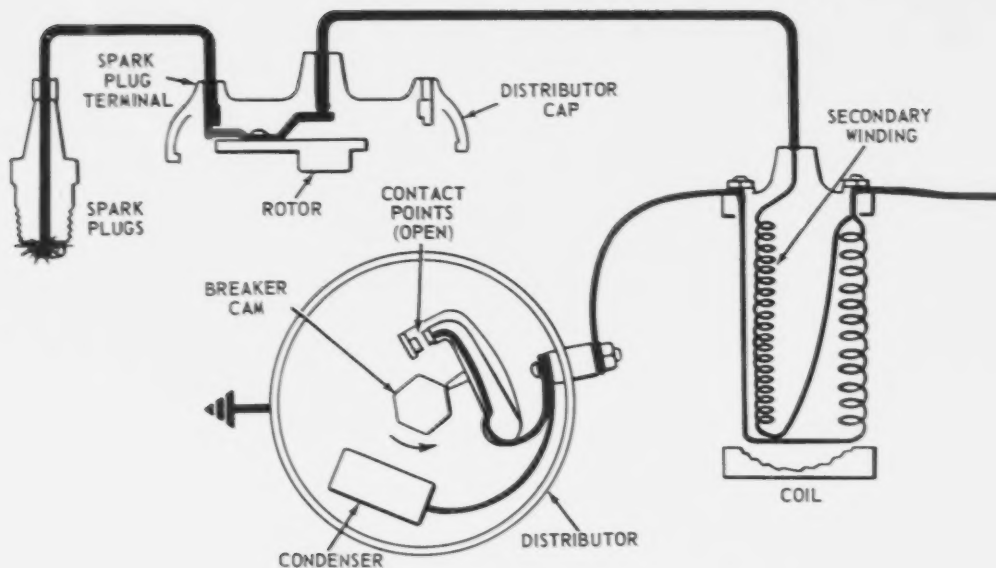


Fig. 10—Operation After The Distributor Points Open

SERVICING THE BATTERY

Battery maintenance is simple, but it is important that service be performed regularly or the battery will soon fail.

Before we discuss how to service the battery, let's look at how it works. Then it will be asy to understand why the battery requires periodic maintenance.

HOW A BATTERY WORKS

Construction

The battery is made up of a number of individual *cells* in a hard rubber case (Fig. 11).

The basic units of each cell are the positive and the *negative plates*.

These plates hold the active materials in flat grids. Charged negative plates contain spongy lead (Pb) which is grey in color. Charged positive plates contain lead peroxide (PbO_2) which has a chocolate brown color.

A *plate group* is made by welding a number of similar plates to a plate strap (Fig. 11).

Plate groups of opposite polarity are interlaced so the negative and positive plates alternate. Negative plate groups normally have one more plate than the positive groups. This keeps negative plates exposed on both sides of the interlaced group.

Each plate in the interlaced plate group is kept apart from its neighbor by porous separators as shown in Fig. 11. The separators allow a free flow of electrolyte around the active plates. The resulting assembly is called an *element*.

After the element is assembled, it is placed in a cell compartment of the battery case.

Hard-top batteries (Fig. 12) have cell connectors which pass through the partitions between cells. The connectors and partitions are sealed so that electrolyte will not transfer between cells. This improves battery performance, since the cell connections are shorter and the cover is more acid-tight.

The main battery terminals are the *positive* and *negative posts*. The positive terminal is larger to help prevent the danger of connecting the battery in reverse polarity.

Vent caps are located in each cell cover. The caps have two purposes: 1) They close the openings in the cell cover through which the electrolyte level is checked and water is added; 2) They provide a vent for the escape of gases formed when the battery is charging.

Each cell in a storage battery has a potential of about two volts. Six-volt batteries contain three cells connected in series, while 12-volt batteries have six cells in series (Fig. 13, top diagram).

For higher voltages, combinations of batteries are used. An example is where two 12-volt batteries are connected in series to serve a 24-volt system (Fig. 13, bottom diagram).

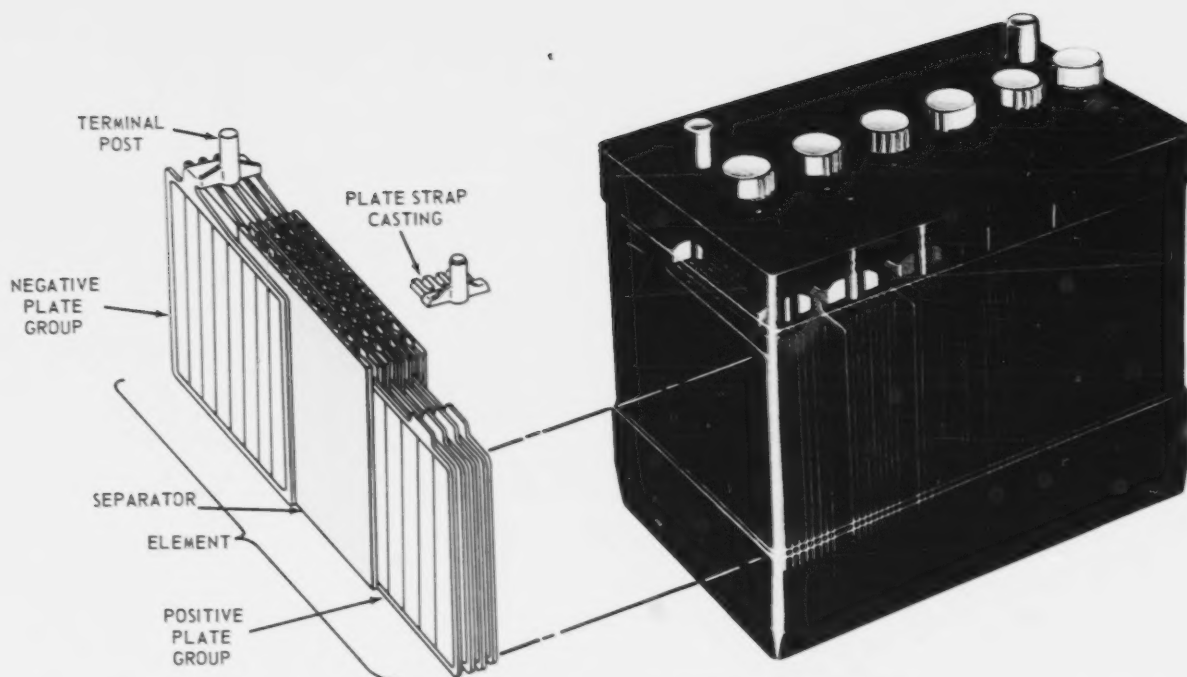


Fig. 11—Construction Of A Storage Battery

Operation Of Battery

The battery produces current by a chemical reaction between the active materials of the unlike plates and the sulfuric acid of the electrolyte (Fig. 14).

While this chemical reaction is taking place, the battery is *discharging*. After most of the active materials have reacted, the battery is *discharged*. It must then be recharged before use.

We'll discuss these two cycles, but first let's see what the electrolyte is made of.

ELECTROLYTE SOLUTION

The *electrolyte* in a fully charged battery is a solution of concentrated sulfuric acid in water (Fig. 15). It has a specific gravity of about 1.270 at 80°F (27°C)—which means it weighs 1.270 times more than water. The solution is about 36% sulfuric acid (H_2SO_4) and 64% water (H_2O) as shown.

The voltage of a battery cell depends upon the chemical difference between the active materials and also upon the concentration of the electrolyte.

DISCHARGE CYCLE OF BATTERY

When the battery is connected to a complete circuit,

Fig. 12—Hard-Top Battery With One-Piece Cover

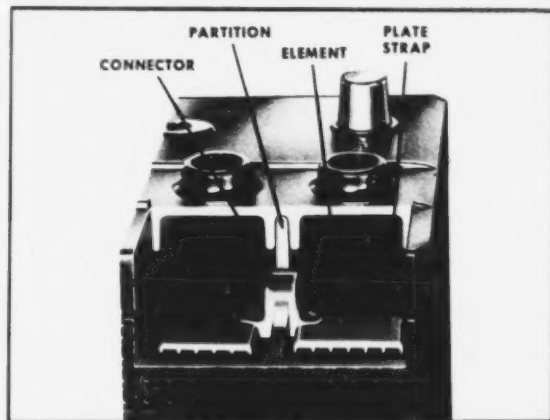
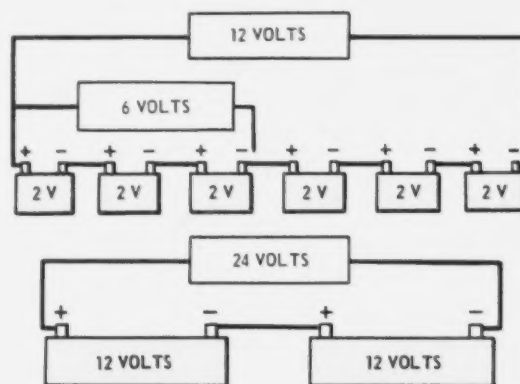
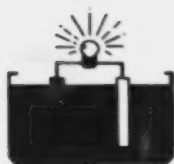


Fig. 13—Battery Cells And Batteries Connected In Series





CURRENT FLOW:
PRODUCED BY
DISSIMILAR PLATES
IN ELECTROLYTE
SOLUTION

Fig. 14—How A Battery Produces Current Flow

current begins to flow from the battery. The *discharge* cycle begins (Fig. 16, left).

This current is produced by a chemical action as shown in the diagram. Study this process to become familiar with the reactions in the battery during discharge.

Note that the material in the positive plates and negative plates becomes similar chemically during discharge, as the lead sulfate accumulates. This condition accounts for the loss of cell voltage, since *voltage depends upon the difference between the two materials*.

As the discharge continues, dilution of the electrolyte and the accumulation of lead sulfate in the plates eventually brings the reactions to a stop. For this reason the active materials never are completely exhausted during discharge.

When the battery can no longer produce the desired

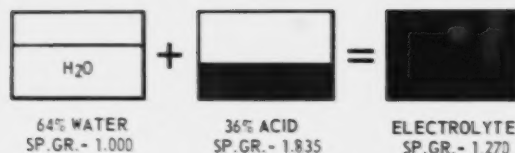


Fig. 15—Battery Electrolyte

voltage, it is said to be *discharged*. It must be recharged by a suitable flow of direct current from some external source before it can be put back in service.

CHARGING CYCLE OF BATTERY

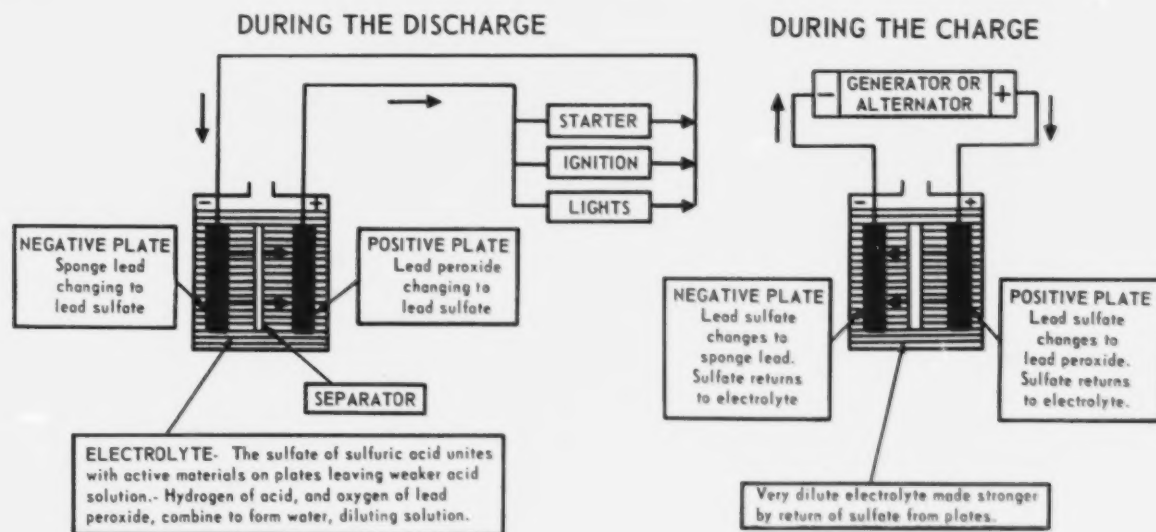
The chemical reactions which go on in the battery cell during the *charge* are the reverse of those which occur during discharge. See Fig. 16, right.

These reactions demonstrate the important fact that water actually takes part in the chemistry of a lead-acid storage battery.

The purity of water for battery use has always been a controversial subject, but it always resolves to the fact that distilled water is the best.

Water with impurities hurts the life and performance of a battery. This is because minerals and other impurities build up on the battery plates, reducing the surface area.

Fig. 16—Chemical Action In Battery During Discharge And Charge Cycles



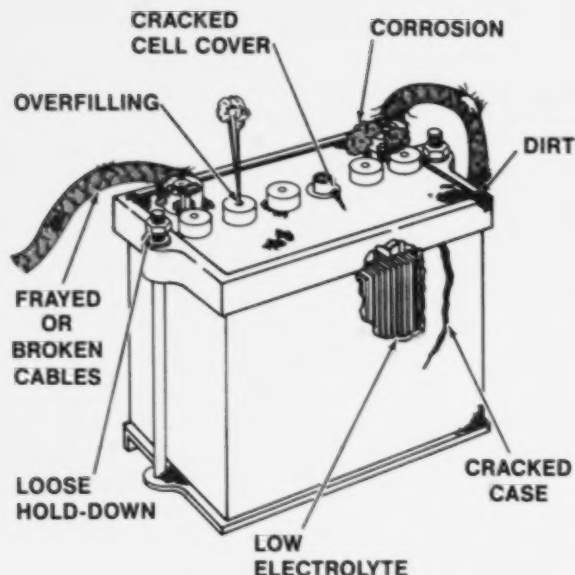


Fig. 17—Things Which Affect The Life Of A Battery

MAINTAINING THE BATTERY

To receive the maximum life from the battery, you must:

- Check the Electrolyte Level Every 50 Hours
- Clean the Battery Every 250 Hours
- Check the Battery Electrical Condition Every 250 Hours
- Charge the Battery When Needed

Fig. 17 shows a poorly maintained battery. This unit will soon fail completely and all these problems could likely have been avoided by good maintenance.

Checking The Electrolyte Level

Every 50 hours of operation, remove all caps from vent wells (Fig. 18). The electrolyte level should be to the bottom of the filler neck—so that the tops of the battery plates are covered (Fig. 19).

CAUTION: GAS FROM BATTERY ELECTROLYTE IS FLAMMABLE. Keep all sparks and flames away from the battery. If the battery has been charging, hydrogen gas is present. This gas will explode in the presence of a spark or flame and possibly cause serious injury to you or others nearby.

If any of the cells require water, fill them with distilled water. Use a battery syringe shown in Fig. 20 to avoid overfilling.

If distilled water is not available, use clean rain water (better than softened water.) Replace caps.



Fig. 18—Removing Vent Caps To Check Battery Electrolyte Level

Battery Don'ts

Don't overfill. When the battery is being charged, the electrolyte will overflow through the vents in the caps and onto the top of the battery. This provides a path for leakage of electricity and will also cause corrosion and deterioration of the metal parts.

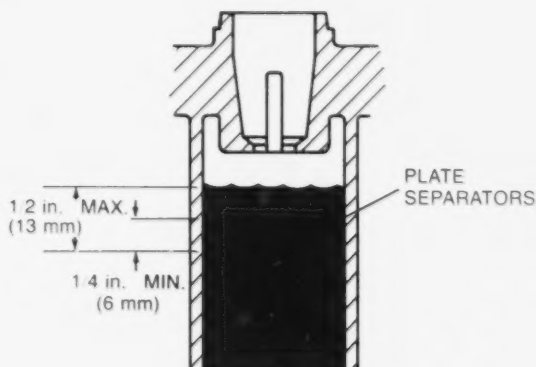
Don't use hard water. The minerals in hard water will leave deposits on the plates and interfere with the chemical action of the battery.

Don't add acid to the battery unless electrolyte is lost by spilling. To operate properly, a battery must have the correct proportions of acid and water.

Don't add water to the battery just before checking specific gravity. If the level is too low, add necessary water and operate in circuit for a few hours to mix water and electrolyte, then check.

Don't add water to the battery in freezing weather

Fig. 19—Proper Level Of Electrolyte In Battery Cells



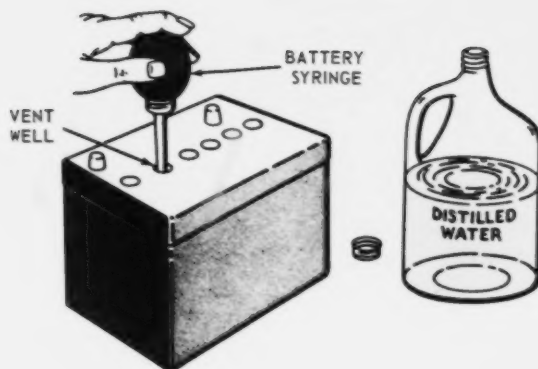


Fig. 20—Adding Distilled Water To Battery

unless it will be operated immediately to allow proper mixing of water with electrolyte.

Cleaning the Battery

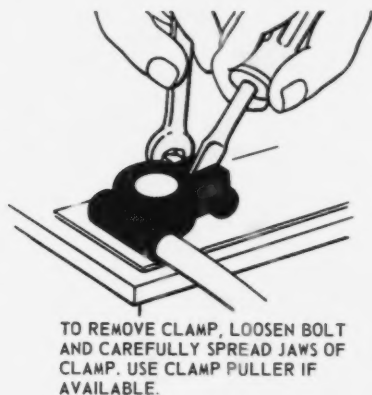
Your battery requires cleaning regularly to prevent dirt, moisture and corrosion from robbing it of its charge.

While the battery is charging, acid spray is carried out of the battery with the hydrogen gas created by the chemical action of the electrolyte. This acid settles on the top of the battery and provides a damp surface for dust and dirt to cling. Posts and terminals become corroded also.

The small amount of acid is enough to provide an electrical path to the metal frame or to the opposite terminal. This will cause the battery to slowly discharge.

Corroded terminals also prevent the generator from recharging the battery when needed. Your battery loses its charge due to the poor contact of the cables

Fig. 21—Removing Battery Terminal Clamp



and terminals caused by a film of corrosion.

Periodically wipe off the battery with a damp cloth about every 250 hours or when very dirty. If corrosion is present, clean the battery as given below.

TOOLS AND MATERIALS NEEDED

To clean a battery, the following tools and materials are needed.

1. Bristle Brush
2. Wire Brush and Sandpaper (or Battery Clamp and Post Cleaning Tools)
3. Small Paint Brush
4. Large Common Screwdriver
5. Battery Clamp Puller
6. Box-End Wrenches (To Fit Terminal Bolts)
7. Baking Soda
8. Container of Water
9. Light Grease or Petroleum Jelly

HOW TO CLEAN BATTERY

To clean the battery, proceed as follows:

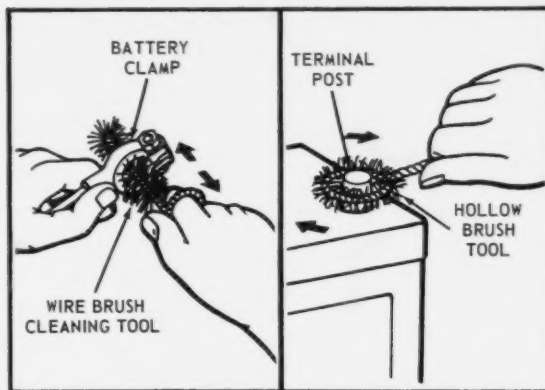


Fig. 22—Cleaning Battery Cable Clamps and Terminal Posts

1. Remove *ground* strap or cable from battery terminal post (Fig. 21). This prevents short circuits caused by accidentally grounding the other terminal with a tool. Use a battery clamp puller if available.

Don't pound on terminal; you may crack the battery top or loosen the post.

2. Remove the other battery cable.

3. Wipe off the clamps with a cloth. Dip the clamps into a mixture of baking soda and water (two tablespoons of soda to a pint [65 mL per liter] of water). This will clean off some of the corrosion and acid.

4. Clean the inside of the clamps with a round wire

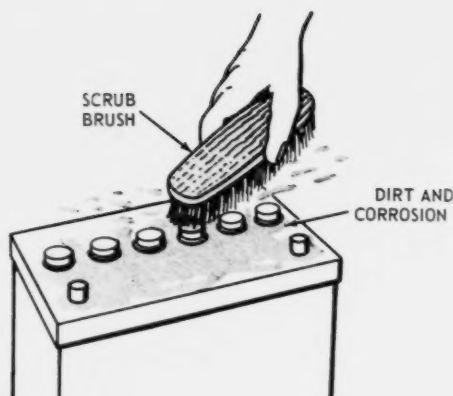


Fig. 23—Removing Dirt With A Bristle Brush

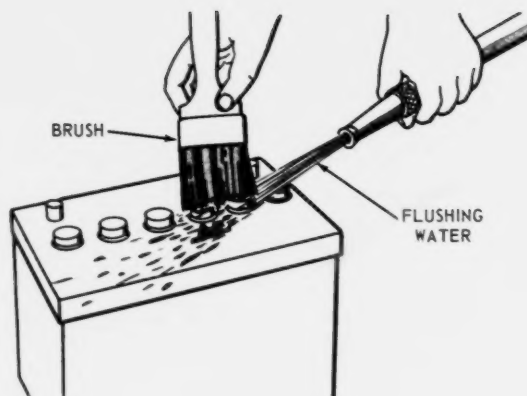


Fig. 25—Flushing Off Top Of Battery

brush cleaning tool (Fig. 22), or roll a small piece of sandpaper around your finger (grit side out) and clean the inside of the clamps. Wipe the clamps clean with a dry cloth.

5. Use a hollow-brush terminal cleaning tool to scrub the corrosion from the terminal posts (Fig. 22). (A stiff wire brush can be used if no tool is available.)

6. Use a bristle brush to remove loose dirt and corrosion particles from the top of the battery (Fig. 23).

7. Brush a fresh mixture of baking soda and water on top of battery and posts (Fig. 24). This will neutralize the acid. Apply solution until foaming stops.

NOTE: Do not allow any of the solution to enter the breather holes in the caps. The baking soda will weaken the acid in the electrolyte. Also be sure caps are securely tightened before cleaning.

8. Flush off residue with clean water (Fig. 25). Protect battery caps from direct stream of water to avoid

flushing dirt into the battery through the vent holes.

If battery is on machine, also flush off surrounding areas with water.

9. Dry the top of the battery with a clean cloth.

10. Inspect the battery for any damage which may require repair or replacement (See Fig. 17).

11. Attach nongrounded cable to proper battery terminal. Be sure the correct connection is made or you may damage the generator or alternator. (Most batteries have terminals of different sizes to avoid mix-ups).

12. Then attach ground cable to the opposite terminal. This will avoid accidental grounding of the other terminal.

IMPORTANT: Do not pound the clamps in place. You may break the seal around the battery posts or crack the battery cover.

Fig. 24—Neutralizing Acid Deposits



Fig. 26—Applying Protective Coat of Grease To Terminals



13. Apply a coating of light grease or petroleum jelly (Fig. 26) to the terminals and clamps to protect them against further corrosion.

14. Examine the breather holes in the top of each battery cap to be sure they are open.

Checking Battery Electrical Condition

CAUTION: Never short across battery terminal posts to check for a spark. This tells you very little about the condition of the battery and an explosion may occur when hydrogen gas is present.

Several devices are available to check the battery more accurately and safely. These include: *hydrometer*, *voltmeter*, *charger-tester*.

Because the *hydrometer* is the most commonly used and least expensive, we will cover use of it only.

Checking Specific Gravity

The state of battery charge is indicated by the specific gravity or weight of the battery electrolyte.

The strength of the electrolyte varies directly with the state of charge of each cell.

To find out how much energy is available from the battery, you need only find out what percentage of sulfuric acid remains in the electrolyte. One of the simplest and most reliable ways to do this is to measure the specific gravity or weight of the solution.

Specific gravity can be measured very quickly by means of a battery hydrometer with a thermometer for temperature correction.

Hydrometers are calibrated to measure specific gravity correctly at an electrolyte temperature of 80° F.

USING THE HYDROMETER

To check the specific gravity of the electrolyte, do the following:

1. Remove battery caps.
2. When checking specific gravity of a battery which has been gassing freely, allow sediment to settle or gas to escape from the sample before taking the reading.
3. Insert the hydrometer into one of the cell openings (Fig. 27). Squeeze the bulb and slowly release it to draw electrolyte into the barrel.

If the electrolyte level is too low to fill the hydrometer, add water to the battery. Operate the engine for a few hours to mix the water and electrolyte so that an accurate reading can be taken.

Hold the hydrometer vertically so the float does not touch the sides. Apply or release some pressure on the bulb until the float in the hydrometer rides freely in the barrel. If the float tends to touch the side of the barrel, shake the hydrometer gently. If the float continues to stick or touch the sides, flush the inside of the hydrometer with soap and water and rinse well before further testing.

If the indicator scale inside the float appears wet or stained, the float probably leaks and your reading will not be accurate.

4. Leave the hydrometer nozzle in the battery cell to avoid spilling acid on the battery or yourself. Be sure your eye is at the level of the liquid when the reading is taken. Readings taken at an angle may be false.

Note the reading indicated by the level of the electrolyte position on the scale.

5. The specific gravity should read from 1.215 to 1.270 (corrected for 80°F; 27°C electrolyte temperature).

For Fahrenheit Temperatures

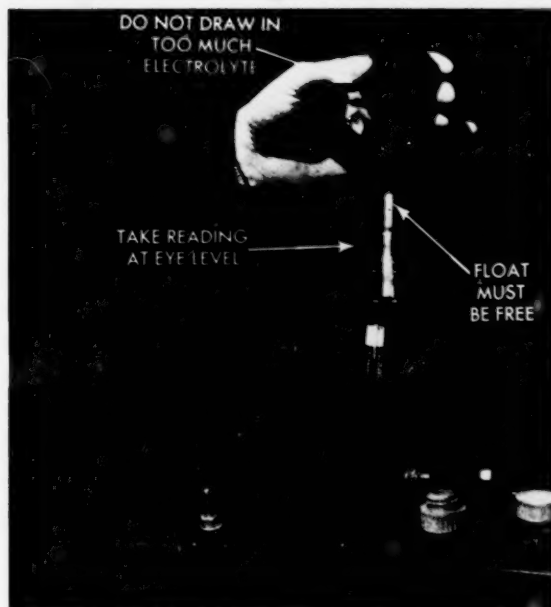
To determine a corrected specific gravity reading when the temperature of the electrolyte is other than 80°F: **ADD** to the hydrometer reading four gravity points (0.004) for each 10° **ABOVE** 80°F.

SUBTRACT four gravity points (0.004) for each 10° **BELOW** 80°F.

This compensates for expansion and contraction of the electrolyte at temperatures above or below the standard.

For example, a specific gravity reading of 1.234 is obtained when electrolyte is at 120°F (See Fig. 28). Since this reading was taken with the electrolyte temperature 40° above the standard, a total of 16 (4x4) gravity points (0.016) is added, giving a corrected reading of 1.250.

Fig. 27—Checking Specific Gravity Of A Battery With A Hydrometer



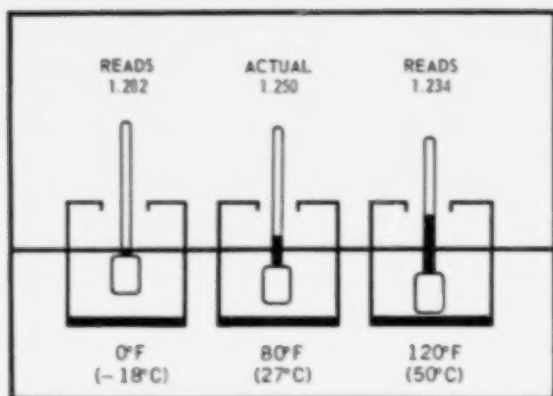


Fig. 28—Correcting Specific Gravity Readings To Allow For Temperature Variations

As a further example, suppose a reading of 1.282 is obtained at 0°F. This reading was taken with the electrolyte temperature 80° below the standard. Therefore, a total of 32 (8×4) gravity points (0.032) is subtracted, giving a corrected reading of 1.250 (which is satisfactory).

For Celsius Temperatures

To determine a corrected specific gravity reading when the electrolyte temperature is other than 27°C: **ADD** to the hydrometer reading seven gravity points (0.007) for each 10° **ABOVE** 27°C.

SUBTRACT seven gravity points (0.007) for each 10° **BELOW** 27°C.

For example, if a specific gravity reading of 1.234 is obtained when electrolyte is at 49°C (See Fig. 28), the electrolyte temperature is 22°C above the standard. A total of 16 (2.2×7) gravity points (0.016) is added, giving a corrected reading of 1.250.

Then, suppose a reading of 1.282 is obtained at -18°C. This reading was taken with the electrolyte temperature 45°C below the standard. Therefore, a total of 32 (4.5×7) gravity points (0.032) is subtracted, giving a corrected reading of 1.250 (which is satisfactory).

6. Return the electrolyte to the cell from which it was taken.

CAUTION: If you accidentally spill some of the electrolyte on your skin or clothing, it could burn you. Rinse with water immediately. Apply baking soda or lime solution to neutralize the acid.

7. Check the remaining cells in the same manner as above.

8. Install battery caps and flush the hydrometer with clean water.

9. Compare the temperature-corrected readings with the chart and descriptions below to determine condition of the battery.

Specific Gravity Reading (Adjusted)

State of Charge

1.260 Sp. Gr.	100% Charged
1.230 Sp. Gr.	75% Charged
1.200 Sp. Gr.	50% Charged
1.170 Sp. Gr.	25% Charged
1.140 Sp. Gr.	Very Little Useful Capacity
1.110 Sp. Gr.	Discharged

The table above shows the state of charge of a typical battery at various specific gravity readings.

IF SPECIFIC GRAVITY IS LESS THAN 1.215

When the specific gravity reading is less than 1.215 (after correction for temperature), the battery may be in satisfactory condition although its state of charge is low. Charge the battery before making further tests. (See following in this chapter for details.)

IF SPECIFIC GRAVITY IS ABOVE 1.270

When the specific gravity reading is above 1.270 (after correction for temperature), the battery may be in satisfactory condition although it is above full charge. In use, its specific gravity should return quickly to the normal 1.215-1.270 range. Make further tests to be more certain of the battery condition.

IF MORE THAN 0.050 VARIATION BETWEEN CELLS

A difference of more than 50 specific gravity points (0.050) between cells indicates an unsatisfactory battery condition. This may be due to an internal defect, short circuit, improper activation, or deterioration from extended use. The battery should normally be replaced.

NOTE: Specific gravity readings do not always give a true indication of the state of charge of a battery. If water has been added recently or acid has been lost through accident or leakage, the reading will indicate a lower state of charge than is actually the case. Therefore, never use specific gravity readings alone to decide the condition of a battery. If unsure of the tests, take the battery to your dealer for further testing.

TESTING WITH ELECTRONIC TESTER

An electronic battery tester may be used to test individual 6-volt and 12-volt batteries (Fig. 29). Disconnect batteries connected in parallel. Do not connect across 24-volt system. This tester may be used to test:

- Battery Condition
- Voltage
- Power

After connecting the tester to the battery, turn the battery rating dial to the rating of battery to be tested (Fig. 30). Select the appropriate settings of the battery voltage switch (6 or 12 volt) and temperature switch to indicate temperature of battery tested.

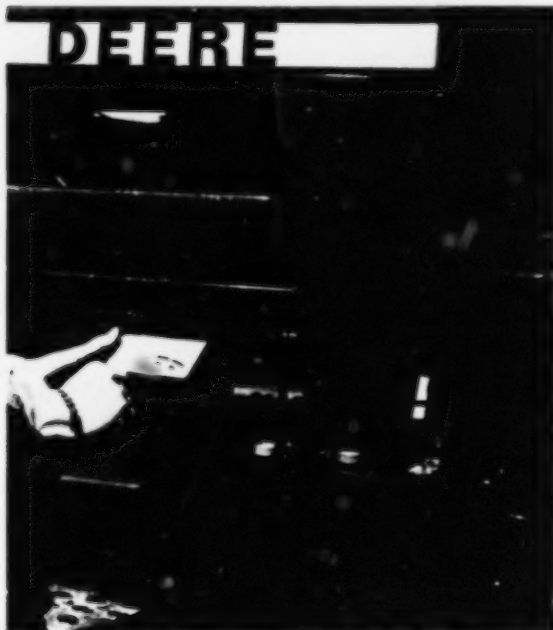


Fig. 29—Test Battery With Electronic Tester

Then select the test to be conducted by dialing the selector switch. For battery condition test, read Red/Green battery condition scale. If it reads REPLACE (pointer in red area) remove battery cables and retest with clips on battery terminals. If battery now tests good, clean corroded terminals.

For voltage test, read scale marked volts. Reading should be at least 12.4 for 12-volt battery and 6.2 for 6-volt battery. If readings are lower, battery is not fully charged. Recharge battery and retest.

Fig. 30—Scales And Switches On Electronic Battery Tester



If voltage will not come up to minimum standards, battery may have a shorted cell.

If voltage reading is too high (for example, above 13 for 12-volt battery or above 6.5 for 6-volt battery) immediately after recharging, a "surface charge" exists. Eliminate surface charge by briefly loading the battery (turn lights on for about 30 seconds).

By performing these tests, the tester can also be used to compare batteries and match batteries.

Charging The Battery

The amount of electrical current a battery can produce is limited by the amount of chemical reaction which can take place within it.

When chemical reaction in a battery has ended through defect or long use, the battery is discharged and can no longer produce a flow of electrical current.

The battery can be recharged, however, by causing direct current from an outside source to flow through it in a direction opposite to that in which it flowed out of the battery.

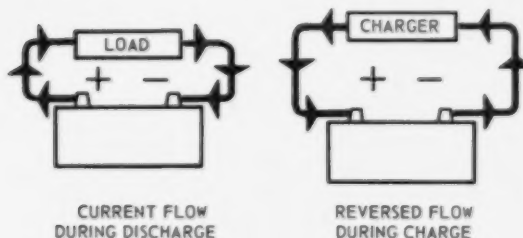
During discharge, current flows from the positive (+) terminal of the battery, through the circuit, and back into the battery at the negative (-) terminal (Fig. 31).

Within the battery, current flow is from the negative to the positive terminal.

To recharge the battery, this flow of current is reversed as shown, restoring the chemicals in the battery to their active state.

The battery then becomes charged and ready to produce electrical current again. The chemical action which takes place within a battery during the discharging and charging was explained earlier in this chapter.

Fig. 31—Current Flow During Discharge And Charge Of Battery



Batteries can be recharged in two ways:

- **Fast Charging**
- **Slow Charging**

Because most operator-owned chargers are "trickle" chargers, we will only discuss slow charging here.

SLOW CHARGING

A battery that is badly sulfated will not accept fast charging without possible damage. So these batteries must be charged at a slow rate.

Be sure to follow the manufacturer's instructions for using the charger. The battery charger shown in Fig. 32 will fast or slow charge and can also be used as a booster battery.

NOTE: Be sure to remove the battery cell caps while charging to allow gas to flow freely from battery.

Charge the battery at a low rate (7% of the battery ampere-hour rating or less) for an extended period of time until fully charged.

A battery is considered fully charged when three consecutive hydrometer readings, taken at hourly intervals, show no rise in specific gravity.

The normal slow-charging period is from 12 to 24 hours.

If a battery's specific gravity has not reached the normal full-charge range (1.215 to 1.270) within 48 hours of slow charging, replace the battery.

Badly sulfated batteries, however, may take from 60 to 100 hours to recharge completely.

Connecting Booster Batteries

Cold weather starting can be made easier by connecting an additional battery (equal voltage) in PARALLEL with the original battery.

Make sure all electrical switches or accessories are turned off and make the last connection or the first disconnect at some point away from the machine battery.

The first jumper cable should connect the positive (+) terminal of the booster battery to the positive (+) terminal of the original battery. The second jumper cable should first be connected to the negative (-) terminal of the booster battery and then to the frame of the machine with the battery being boosted. NEVER REVERSE THE CONNECTIONS.

Always break the connection at the booster battery first.

Some portable battery chargers can be used as a booster battery (Fig. 32).

IMPORTANT: *Never use booster cable from a 12-volt battery to a 6-volt system as it may damage system.*

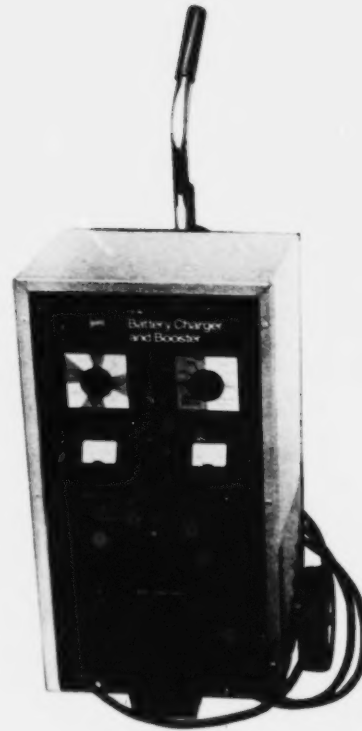


Fig. 32—Battery Charger

SELECTION OF BATTERIES FOR REPLACEMENT

When replacing batteries, be sure to replace the battery with one at least equal in size to the original.

For cold weather starting, the battery must be powerful enough for the cranking job.

Fig. 33 shows how the load on the battery gets bigger when it is colder. At -20°F (-30°C), the battery has only 30% of its full cranking capacity. At the same time, greater load is put on the battery by the colder engine when starting.

In effect, at cold temperatures the battery is "smaller" while the engine is "larger".

If the replacement battery is smaller than the original, the engine will surely be harder to start in cold weather.

There are many times in the heat of summer when engines are just as hard to start as in the winter especially when an air conditioner is added to the engine load. Therefore, use the same method of matching battery power to the engine in hot areas as you would in colder climates.

Other Factors In Battery Selection

When replacing batteries, be sure to replace the battery with one *at least equal* in size (ampere-hours rating) to the original.

A *larger* battery than the original may be needed if added accessories put a larger load on the battery.

An extra-output alternator may be the answer in cases where electrical loads are excessive or when operating mostly at slower speeds. This will help keep the battery charged and increase its service life.

The cheapest battery is not always the best buy for replacement. For example, three batteries in the same group size may vary in price, but they also vary in ampere-hours rating, in construction, and in warranty period. Divide the price by the months of warranty, and you may find the most expensive batteries are really the most economical, per month of expected service.

A final word on replacing batteries: One out of every four batteries returned for warranty has nothing wrong with it except that it is discharged. *Be sure to trouble shoot the battery before you replace it.*

SAFETY RULES FOR BATTERIES

1. To avoid injury from a spark or short circuit, DISCONNECT THE BATTERY GROUND STRAP (Fig. 34)

Fig. 33—How Cold Weather Affects The Battery And The Engine When Starting

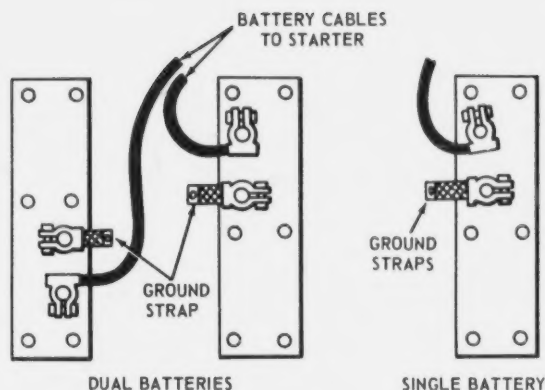
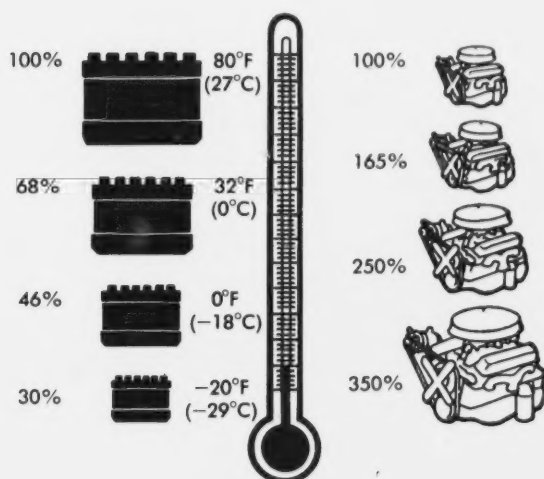


Fig. 34—Installation of Typical Batteries

when working on any part of the electrical system or engine. This will also prevent accidental starting.

2. Disconnect the battery cable (Fig. 34) before fast charging the battery in the machine. This is especially important with a.c. charging systems where the alternator can be damaged.

3. When removing the battery, disconnect the battery ground strap first. When installing the battery, wait until last to connect the ground strap.

4. Never reverse the polarity of the battery connections. In general, systems with a.c. charging have negative grounds (-), while systems with d.c. charging can have either positive (+) or negative (-) grounds. Reversing the polarity may damage some components and wiring in the system.

5. DO NOT ATTEMPT TO POLARIZE THE ALTERNATOR on a.c. circuits after connecting the battery. No polarization is needed. Any attempt to do so may damage the alternator, regulator, or circuits. However, if your machine has a generator, it should be polarized (see later under "Generator Service").

6. If booster batteries are used to start an engine, connect the (+) terminal of the booster battery to the (+) terminal of the dead battery with a jumper cable. Then, connect the second cable to the (-) terminal on the booster battery. Make the last (-) connection to a good ground on the machine with the dead battery. Disconnect in reverse order.

7. Do not attempt to recharge or jump-start a frozen battery. Check for ice in each cell of the battery.

8. When using booster batteries, prevent fire hazards as follows: a) When possible, use cables with a switch in the line. b) Always "rock" the connector clips to make sure they are making good contact. c) Always put the machine in PARK. d) Never jump start by touching connectors to the starter motor. The machine can suddenly lurch and crush you.

9. Don't lay tools down by a battery. An accidental nudge and a tool can contact a battery terminal, and short circuit the battery.

10. **GAS FROM BATTERY ELECTROLYTE IS FLAMMABLE:** Keep sparks and flame away from the battery. When charging the battery, gas is created rapidly. Be sure the room where batteries are charged is well-ventilated.

11. BATTERY ACID IS HARMFUL ON CONTACT

If battery electrolyte spills:

1. Remove affected clothing.
2. Rinse affected skin with clear water for 10 or 15 minutes.
3. Flood eyes with clear water for 10 or 15 minutes. Force the eyes open so water can flush them.
4. Then, see a doctor.
5. Don't use any medication or eye drops unless prescribed by a physician.

MAINTENANCE-FREE BATTERIES

Maintenance-free batteries operate similar to the conventional style battery. The construction is somewhat different than other batteries. The plates in maintenance-free batteries are made of lead-calcium which reduces gassing by as much as 97 percent over conventional batteries with lead-antimony plates.

Maintenance-free batteries are vented but most do not have vent caps. This reduces acid spillage and thus reduces the potential for corrosion on the battery terminals.

The vent strip may be removed from the top of some maintenance free batteries to expose the electrolyte. A hydrometer can then be used to check the battery and water may be added if necessary. However, because of the reduced gassing in maintenance-free batteries with lead-calcium plates, additional water normally is not required for the life of the battery.

Most maintenance-free batteries with lead-calcium plates are activated, charged, and ready for service when shipped from the factory. Because of a low rate of discharge, they have a longer shelf life than conventional wet-charged batteries. A maintenance-free battery may have a shelf life of 12 months or longer, depending on storage temperature.

SERVICING SPARK PLUGS

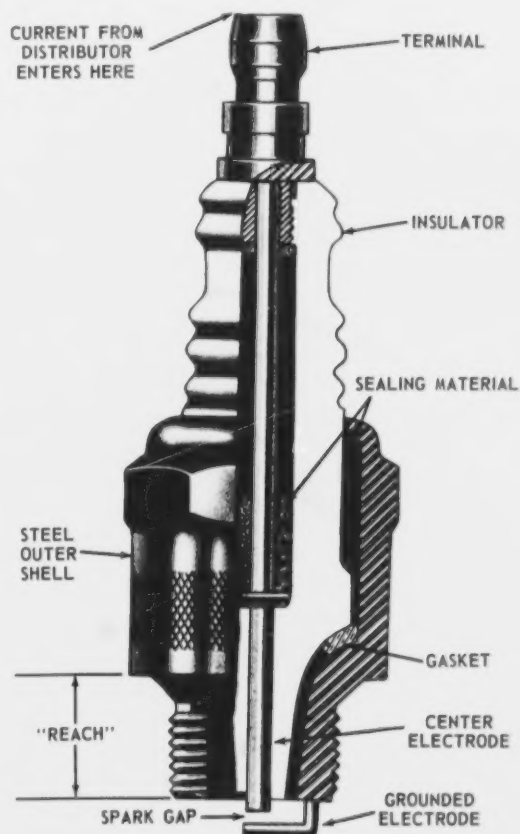
Fouled or damaged spark plugs can rob a spark-ignition engine of power and economy. For example, if spark plugs are badly fouled, the power and fuel lost in only a few weeks can pay for a new set of plugs.

SPARK PLUG OPERATION

A spark plug has two electrodes separated by a gap (Fig. 35). High voltage current from the distributor enters the top of a spark plug, travels down the center electrode, and jumps the gap at the bottom to make a spark.

The width of the spark plug gap is vital to both the size of the spark and to proper timing of the ignition.

Fig. 35—Spark Plug Construction



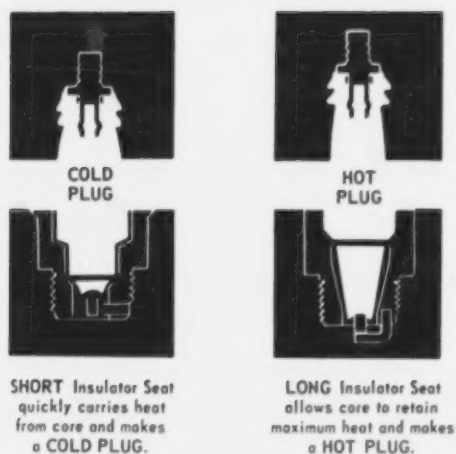


Fig. 36—Heat Range Of Spark Plugs

HEAT RANGE OF PLUGS

The heat range of a spark plug is as important as the gap setting.

The term *heat range* refers to the plug's ability to transfer the heat at the firing tip to the cooling systems of the engine. This is determined by the *distance the heat must travel*.

As shown in Fig. 36, the end of a plug insulator that has a long nose or cone is further from the cooling system. Therefore, heat at the end will travel further. This type of plug will then run *hot*.

In contrast, the end of a short insulator cone is closer to the cooling system and heat will transfer faster. This plug will then operate *cooler*.

Engine design and operating conditions will decide which type of spark plug—hot or cold—should be used. Generally, an engine which operates at fast speeds or heavy loads, and thus hotter, will require a *colder* plug so that the heat will transfer faster. On the other hand, a *hotter* plug will be used in an engine that operates at low or idle speeds most of the time. For normal engine operations, a plug that falls somewhere between hot and cold is used.

The heat range of a plug is usually shown by a number on the plug. A higher number (such as "18") is hotter than a lower one (such as "15").

When the correct heat range is used, the plugs operate at the proper temperatures to burn themselves free of carbon.

If plugs operate too hot, preignition will occur.

If plugs operate too cold, fouling will result.

TOOLS AND MATERIALS NEEDED

To service spark plugs, the following tools and materials are needed:

1. Spark plug socket wrench
2. Pan of cleaning solvent (not gasoline)
3. Wire brush
4. Blade-type file
5. Wire-type plug gap gauge (inch or metric, as required)
6. Set of new plug gaskets (if available)
7. Torque wrench (inch or metric, as required)

REMOVING SPARK PLUGS

Spark plugs should be removed and serviced every 500 hours, or sooner if recommended in the operator's manual.

Observe these practices when removing plugs:

1. Pull the wire from the plug by grasping the terminal, *not* by pulling on the wire (Fig. 37 left).
2. Use a deep-well socket (Fig. 37) to loosen the spark plug. (A special spark plug socket with rubber insert is even better.) Hold the socket straight to prevent breaking the insulator.
3. After loosening the plug but before removing it, always clean the area around the spark plug by blowing, wiping, or brushing (Fig. 37). (Be sure to protect your eyes.) This will prevent dirt from falling into the cylinder after removal.
4. Remove the plugs and place them in order to match the cylinder each came from (Fig. 37, right). The condition of the spark plug can tell you a lot about the operation of a particular cylinder. Also remove the plug gaskets (if used).

ANALYZING CONDITION OF SPARK PLUGS

Check the condition of all spark plugs removed—even if you are replacing them. The appearance of the plug's firing end can tell you whether your engine is using too much oil, overfueling, misfiring, or overheating. Condition of plugs may also warn you of a wrong grade of fuel or an incorrect spark plug.

Study the chart at the right to become familiar with spark plug conditions and what they mean.

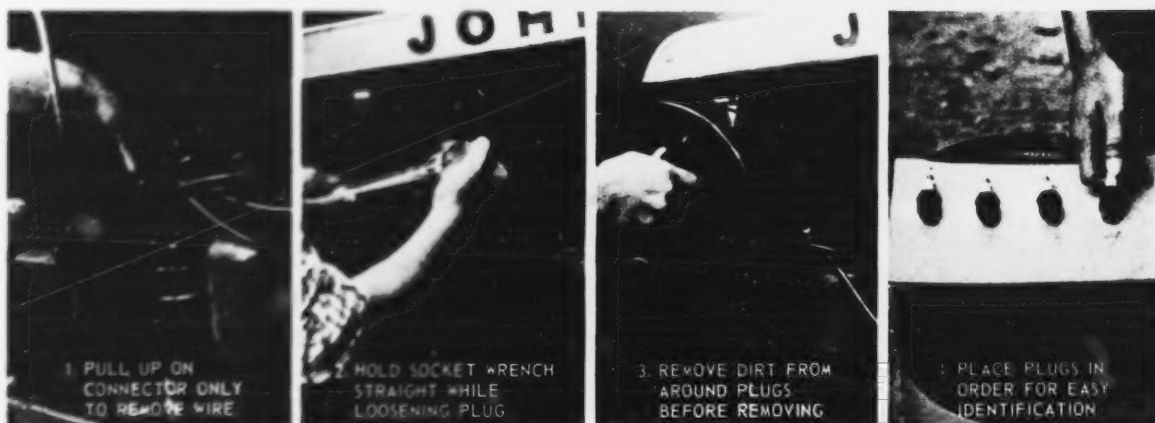


Fig. 37—Removing spark plugs

SERVICING OF SPARK PLUGS

Spark plug service has three basic jobs:

- Inspection
- Cleaning
- Gap adjustment

Most engine manufacturers recommend a specific time interval for ignition services. Follow this timetable very closely.

Inspecting Spark Plugs

When inspecting the plugs, look for the abnormal wear shown in the Spark Plug Condition Chart.

SPARK PLUG CONDITION CHART					
Condition	Identification	Caused By	Condition	Identification	Caused By
Oil Fouling	Wet, sludgy deposits.	Excessive oil entering combustion chamber through worn rings and pistons, excessive clearance between valve guides and stems, or worn or loose bearings.	High Lead Deposits	White, powdery deposits.	Highly leaded gasoline (premium gasoline).
	Dry, black, fluffy deposits.	Incomplete combustion caused by too rich a fuel-air mixture or by a defective coil, breaker points or ignition wiring.		Hard, baked on black carbon.	Too cold a plug. Weak ignition, defective fuel pump, dirty air cleaner, too rich a fuel mixture.
Gas Fouling	White, burned, or blistered insulator nose and eroded electrodes	Engine overheating caused by improper ignition timing, wrong type of fuel, loose spark plugs, too hot a plug, or low fuel pump pressure.	Carbon Fouling	Hard and scratchy.	Formed when fine sand particles combine with anti-knock compounds in fuel. Most common in dusty areas. The plugs cannot be cleaned.
Burned or Overheating	Rusty brown to grayish-tan powder deposit and minor electrode erosion.	Regular or unleaded gasoline.	Silicone Deposit	Splattered deposits.	Deposits from misfiring loosened when normal combustion chamber deposits are restored after new plugs are installed. During high-speed run, these deposits are thrown into plug.
Normal Conditions			Splashed Fouling		

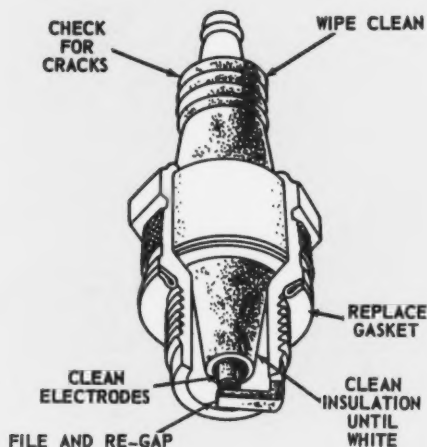


Fig. 38—Spark Plug Maintenance

Then decide whether to recondition or replace the plugs.

Remember, if one plug is replaced, all the plugs should be replaced to get the full advantage of new plug performance and economy. This does not apply, of course, if unusual conditions cause premature failure to just one in a fairly new set of plugs.

Normally, replace the whole set of plugs after long intervals of use. Normal wear can double the voltage requirements of a spark plug even in a short period of time.

Cleaning Spark Plugs

NOTE: Do not use a power wire brush to clean the plugs. Most makers of plugs do not recommend this.

1. Badly fouled plugs should be replaced. It is doubtful if sand blasting or liquid cleaning will remove all the deposits from such plugs.
2. If the plugs have moderate deposits, you may take them to your dealer for machine cleaning. However, if a sand-blast machine is used to clean the plugs, some engine manufacturers void the warranty on the engine.
3. Clean wet, oily plugs with a cleaning solvent which dissolves petroleum deposits (but *not* gasoline).
4. Clean the threads with a wire hand brush.
5. To allow room for filing, bend the ground electrode away from the center electrode.

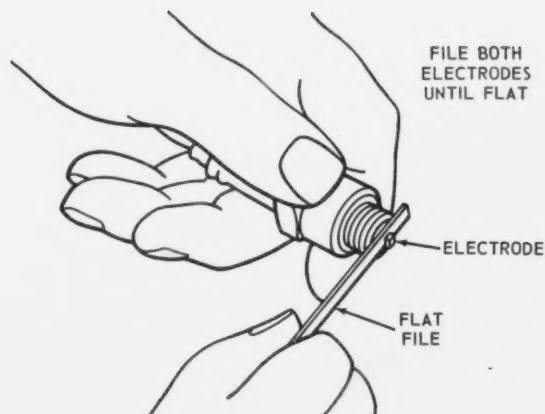


Fig. 39—Filing Spark Plug Electrodes Until Flat

6. File both electrodes (Fig. 39) until they have flat bright surfaces (like a new plug). However, remove as little material as possible.

These flat surfaces reduce the voltage required to fire the plug consistently. Rounded electrodes require higher voltages to fire the plug.

7. Bend ground electrodes back to original position.
8. Clean or blow metal filings from plug.

Gap Adjustment of Spark Plugs

1. Whether the plug is new or used, always check the gap before you install the plug (Fig. 40). Refer to your operator's manual for the correct gap (usually .020, .025, or .030 inch; 0.5, 0.6 or 0.8 mm).
2. Don't use a flat gauge to check the spark plug gap. A flat gauge doesn't give an accurate indication of the true gap. A wire gauge will fit the contour of irregular surfaces.

3. Bend the ground electrode, as necessary, with a gap setter (usually part of the spark plug gauge). See Fig. 41. Check the gap with the proper thickness gauge.

IMPORTANT: Never bend the center electrode. Doing so may crack or break the insulator tip.

INSTALLING SPARK PLUGS

As stated earlier, spark plugs are cooled by the coolant in the passages of the engine head. For this reason, be sure the area around each spark plug post is absolutely clean before installing plugs. New spark plugs may result in some increase in power and decrease in fuel consumption.

1. Install the plugs and tighten with your fingers. Be sure to use a gasket—unless the plug has a tapered seat (gaskets aren't required for this type of plug).

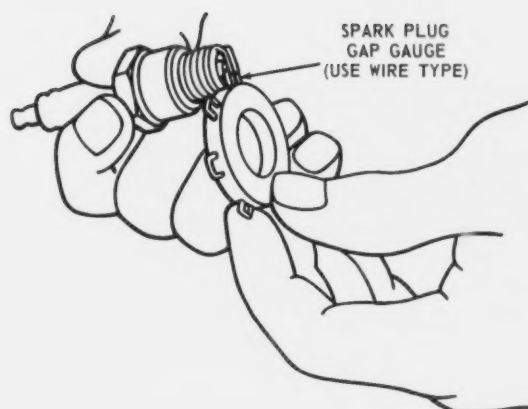


Fig. 40—Checking Spark Plug Gap (With Wire-Type Gauge)

You should use new gaskets when installing plugs. Old gaskets will be flattened by tightening; however, they may still be usable.

A properly tightened gasket conducts almost 50 percent of the heat flow from the plug to the engine head and coolant.

2. Tighten plug with a spark plug socket and torque wrench. The operator's manual will tell how much torque to apply. For example, the average 14 mm threaded plug is usually tightened to about 25 ft-lbs (34 N·m) torque.

If the plug is not tight enough against the gasket, the plug will overheat.

However, if the plug is too tight against the gasket, the porcelain insulator may break. Also, the plug could be distorted and change the gap between the electrodes.

Fig. 41—Adjusting Spark Plug Gap

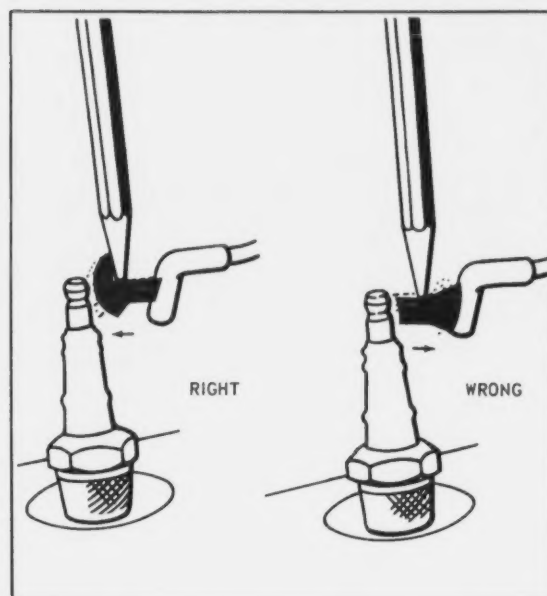
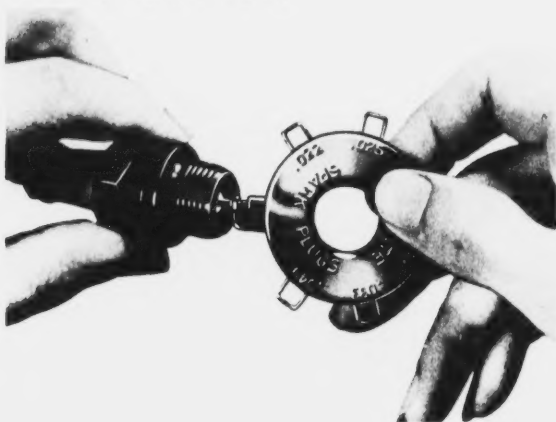


Fig. 42—Checking Polarity At The Spark Plug

3. Check the condition of the spark plug wires before reinstalling. If the insulation is cracked or extremely soft, replace the wires. Defective insulation will allow electrical leaks and misfiring.

Check the plug connectors for looseness and bad fit. If the connectors are not repairable, replace the wires.

4. Check the polarity of the spark at the spark plug (Fig. 42).

To check the polarity, hold the metal connector of the spark plug wire about 1/4 inch (6 mm) from the spark plug terminal (Fig. 42). Insert the point of an ordinary lead pencil as shown.

If the spark feathers on the plug side, the polarity is correct.

If the spark feathers on the connector side, the polarity is reversed. To correct, interchange the primary wire connections on the ignition coil.

SERVICING THE DISTRIBUTOR

As we have discussed earlier, the *distributor* controls the spark plug operation and engine timing on spark-ignition engines. Therefore, maintenance of the distributor is important to maintain the efficiency and power of the engine.

Badly pitted or burned breaker points, for example, can cause hard starting and misfiring at the spark plugs. A poorly timed engine can also cause poor

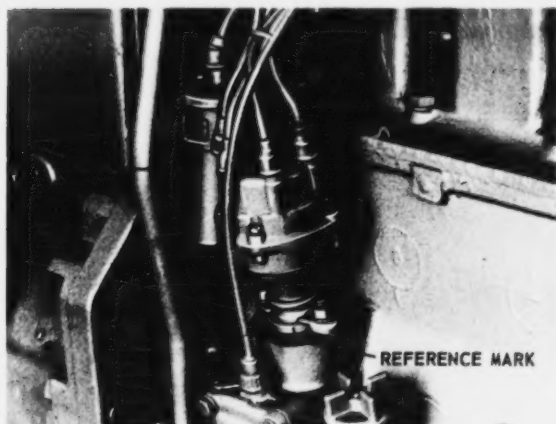


Fig. 43—Ignition Distributor and Coil

fuel economy, loss of power, and possible damage to the engine.

If the timing is late, the fuel-air mixture does not burn completely, valves will burn, fuel is wasted, and power is lost. If the timing is too early, pre-ignition occurs.

You should perform maintenance of the distributor every 500 hours or less of operation; refer to your operator's manual.

Your engine may be equipped with either a *conventional* ignition system or a *transistorized* system. We will discuss their differences later, but now let's examine the distributor, which is part of both systems.

OPERATION OF THE DISTRIBUTOR

As the distributor drive shaft turns, the breaker cam lobe pushes the breaker lever rubbing block. This action

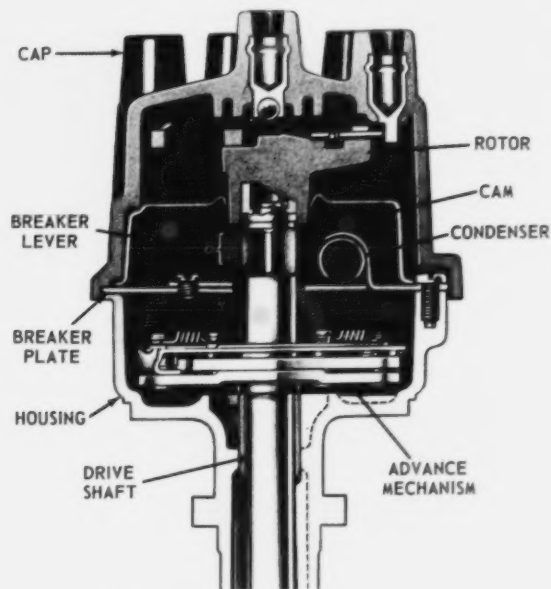


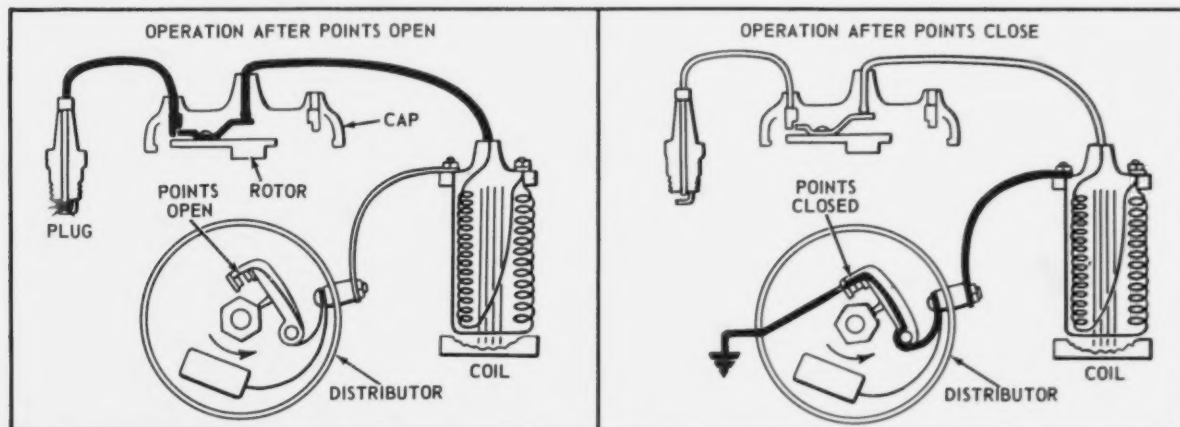
Fig. 44—Cutaway View Of Distributor

opens the contact points, stopping the current flow in the coil primary circuit. See at left in Fig. 45, below.

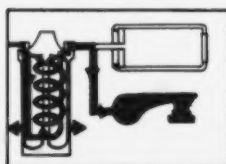
The collapsing field and the resulting high-voltage surge in the coil's secondary winding forces current into the center terminal of the distributor cap as shown in red. The distributor rotor picks up this current and delivers it to the proper spark plug to fire the engine.

Meanwhile, the distributor cam lobe has moved away from the rubbing block and spring tension brings the

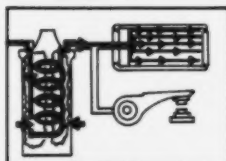
Fig. 45—Basic Operation Of The Distributor And Coil



① Steady, straight current flow through coil primary, points closed.



② As points open, current flows into the condenser.



③ High charge in condenser flows out.

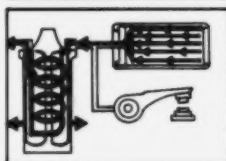


Fig. 46—Operation Of Condenser

points back into contact (see at right in Fig. 45). The primary circuit is again complete and current flows until the next lobe opens the points. The cycle then repeats itself.

In this way a spark is created as each lobe of the cam opens the contact points. The entire cycle for each spark takes place at a very high speed.

CONDENSER OPERATION

A condenser is really an electrical capacitor. Someone long ago started calling them condensers and the word stuck.

In a mechanical ignition, the condenser (capacitor) receives and stores electrical current briefly, while the contact points are opening (Fig. 46). With the current flowing into the condenser while the contact points open, the current can't arc across the points and burn them.

But, a condenser can only hold so much. When it is fully charged, it discharges its current in one burst. Since the points are fully open by this time, the burst of current flows back to the coil. At the coil, the burst of current collapses the magnetic field and induces a tremendous voltage in the secondary circuit. This voltage flows to the spark plug and jumps the spark plug gap producing the ignition spark for the engine.

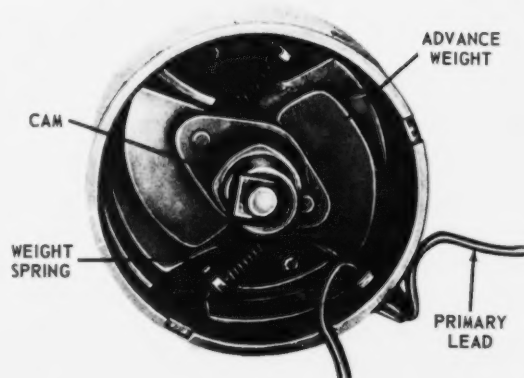


Fig. 47—Centrifugal Advance Mechanism

Centrifugal Advance on Distributor

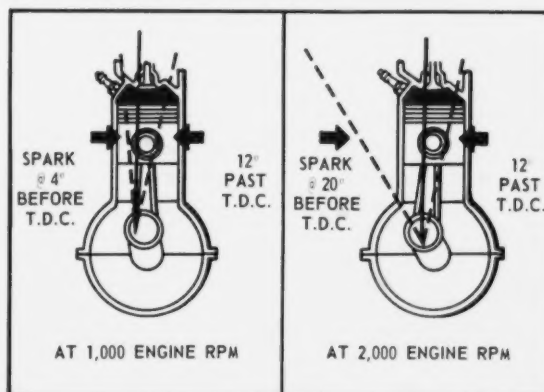
Basically, an *advance mechanism* (Fig. 47) is a device which times the ignition spark to occur at a certain time determined by engine speed. Why is a spark advance necessary?

The distributor must deliver the spark to the engine when it is most effective. The most effective time is determined by the position of the piston and the time required to ignite the fuel-air mixture in the engine cylinder.

What the advance mechanism does is adjust the distributor timing to allow for speed changes so that the spark will occur at the right time even though the engine speed changes (Fig. 48).

The most common advance mechanism is the *centrifugal advance* (Fig. 49). This device has two weights, a weight base, and two springs.

Fig. 48—Spark Timing Of The Engine



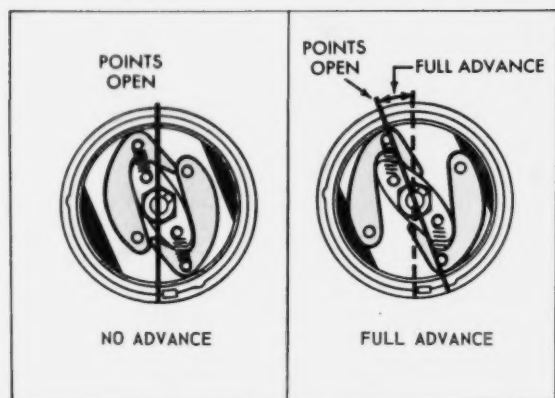


Fig. 49—Operation Of Centrifugal Advance

The weight base is part of the distributor drive shaft. The springs are connected to the base, while the weights are placed on the base. The distributor breaker cam has two pins which connect it to the springs and weights. The pins also set in slots in the base.

At idle speeds the breaker cam is "pinned" to the base and rotates with the drive shaft. The cam lobes then open the points at a preset time—such as 4 degrees before top dead center.

As the engine speeds up, centrifugal force throws the weights out against spring tension (Fig. 49). This turns the breaker cam so the cam lobes are now striking the breaker lever earlier. Therefore, the contact points open ahead of time.

The higher the speed, the farther the weights are thrown out. And the farther the weights are thrown, the more they turn the breaker cam and the more the spark is advanced.

Fig. 50—Vacuum Advance Mechanism

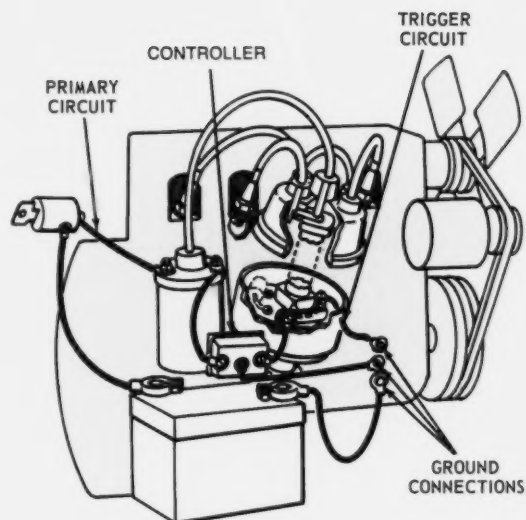
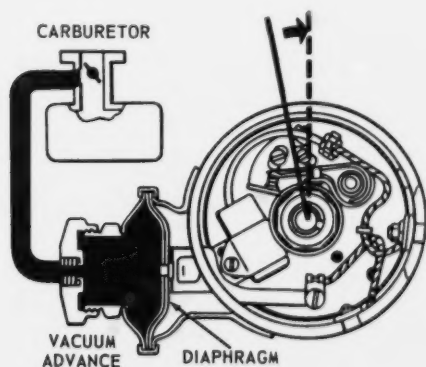


Fig. 51—Simplified Electronic Ignition

When the engine slows down, the springs return the breaker cam and weights to their original position, thus retarding the spark timing.

Vacuum Advance on Distributor

For greater fuel economy, an extra advance mechanism is used on some distributors. This is the *vacuum advance* (Fig. 50).

A vacuum can develop in the engine intake manifold, allowing less fuel and air into the cylinder. Since a lean fuel-air mixture will burn slower, ignition must take place sooner in the cycle than even the centrifugal advance can provide. So a vacuum advance is used to advance the spark still further.

The vacuum advance uses an air-tight diaphragm connected to an opening in the carburetor by a vacuum passage (Fig. 50). The diaphragm is connected by linkage to the distributor housing or the breaker plate.

When a vacuum at the intake manifold draws air from the diaphragm chamber, it causes the diaphragm to rotate the distributor breaker plate in the opposite direction of drive shaft rotation. This moves the breaker lever to contact the breaker cam lobes sooner and thus advances the spark.

ELECTRONIC IGNITION

The components of an electronic ignition system (Fig. 52) are much the same as the components of a mechanical ignition system.

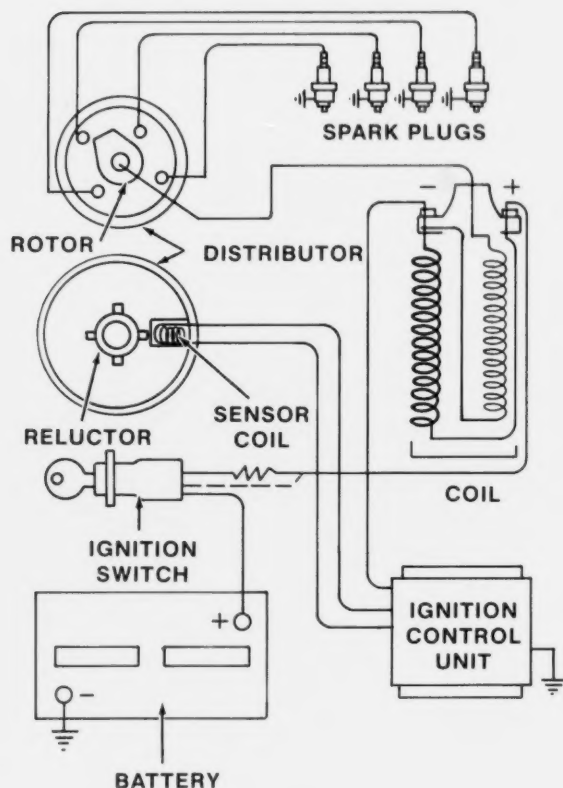
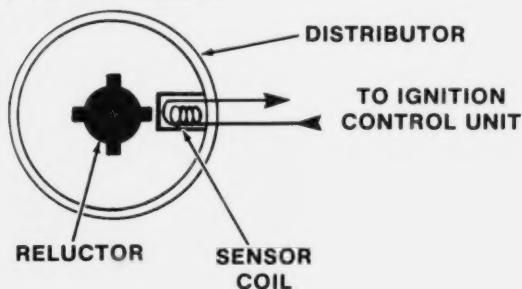


Fig. 52—An Electronic Ignition

The main difference in the two systems is that the electronic battery system uses a solid state ignition control unit with a reluctor and sensor to time spark delivery in place of breaker points and a condenser.

When the ignition switch is turned on, battery current flows through the switch to the coil and through the primary winding to the ignition control unit. A strong electromagnetic field is developed around the winding in the sensor coil (Fig. 53).

Fig. 53—Sensor and Reluctor



When one of the reluctor projections enters the magnetic field around the sensor coil its presence is sensed, and the sensing element in the ignition control unit breaks the primary circuit. Breaking the primary circuit collapses the electromagnetic field around the primary coil windings. This collapsing field induces a high voltage in the secondary coil. The voltage is routed to the distributor rotor (Fig. 54) through the high tension lead. If timed correctly, the rotor, at that moment, is in position to contact the wire to the correct spark plug. The current flows to the spark plug, and jumps the spark plug gap to make

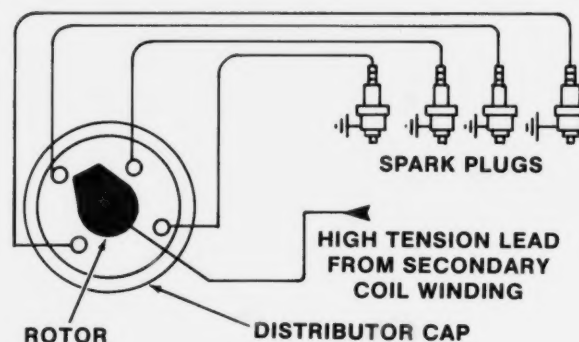


Fig. 54—Rotor

the ignition spark. The entire cycle then starts over to fire the next spark plug in order.

ELECTRONIC IGNITION MAINTENANCE

The ignition control unit is sealed and requires no maintenance. There is no service to be performed on the sensor coil and reluctor with the exception of setting the air gap. To set the air gap:

1. Loosen the sensor coil adjusting screw.
2. Align one of the reluctor teeth with the sensor.
3. Insert a nonmagnetic feeler gauge, usually about .008 inch (0.2 mm), between the reluctor tooth and sensor. Move sensor against the feeler gauge and tighten the screw.

The rest of the system requires the same maintenance as a mechanical ignition system.

CHECKING CONDITION OF DISTRIBUTOR

1. Clean outside of distributor housing and cap before removing cap. Use a small amount of cleaning solvent if necessary. Do not use water; it may cause short circuits. Do not allow any dirt to enter distribu-

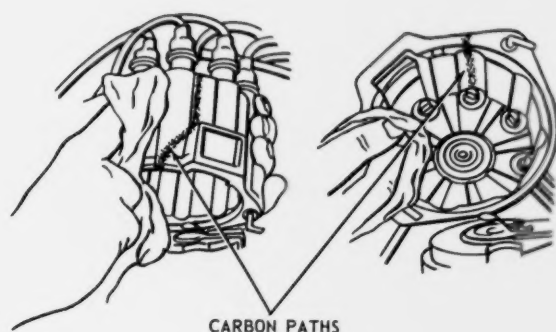


Fig. 55—Carbon Paths On Distributor Caps

tor. A clean cap will help prevent electrical shorts or crossfiring during operation.

2. Remove cap and wipe interior clean with a dry cloth. Dust, moisture or oil deposits must be removed. If carbon paths are present, (Fig. 55) the cap must be replaced. These paths are caused by electricity flowing between terminals or between terminals and a ground. Accumulation of dirt and moisture cause these paths to form. Once the path is formed, it will continue to conduct current and eventually burn through the cap.

Check to see if ventilator holes are open. If ozone gas (created by sparking between the rotor and terminals) is trapped, moisture will combine with the gas to form an acid which will corrode metal parts.

3. Inspect the distributor cap for chips or cracks.

Replace the cap if it is cracked. If the carbon button in the center of the cap is worn excessively, chipped or cracked, replace the cap.

4. Remove the rotor (Fig. 56) and clean it. Inspect for cracks or excessive burning of the metal strip. Replace the rotor if these signs of damage are present.

5. If a dust cover is used, remove it and check the condition of the felt seal. If the seal is worn, replace the seal. Dirt may enter past a worn seal and cause rapid wear of the cam lobes or rubbing block on the points.

6. Check the centrifugal advance mechanism (See Fig. 47). Turn the distributor shaft in the direction of normal rotation. It must rotate freely for a short distance and return to its original position when released. If it doesn't, have it checked by a service shop.

7. Inspect the contact surfaces of the breaker points.

If the surfaces are rough but show only slight pitting and metal deposits (Fig. 57, A), file them smooth with an ignition file (B). Keep the surfaces parallel and flat. Do not use sandpaper or emery cloth; particles may

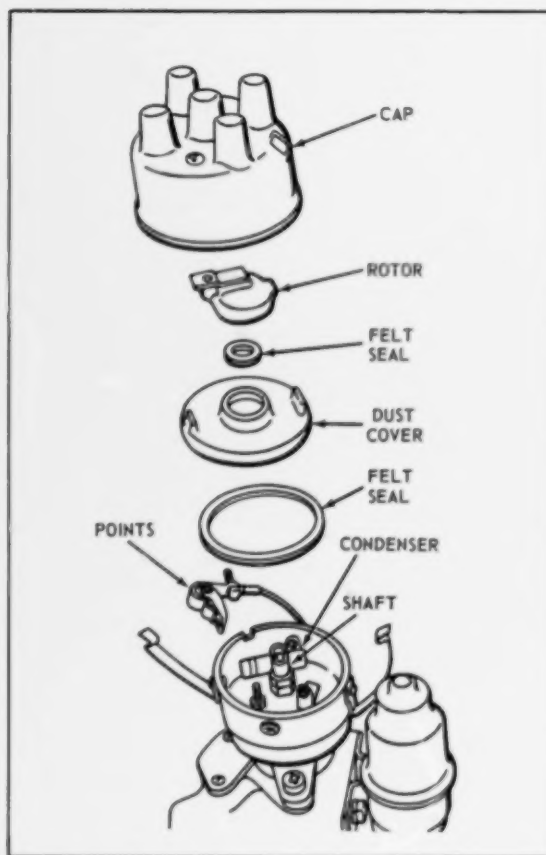


Fig. 56—Distributor Rotor

become imbedded in the contact surfaces and cause the points to burn. Be sure that a large area of contact is maintained between the surfaces. Remove just the high spots; all pits do not need to be completely removed.

If the points are badly pitted with very rough surfaces (Fig. 57, C), replace them. See "Replacing Breaker Points" on the following page.

Burned points may be caused by any one of the following reasons:

- Oil or Foreign Material on the Contact Surfaces
- Condenser of Improper Capacity
- Incorrect Gap Adjustment
- Poor Alignment of Contact Surfaces

If the breaker points must be replaced, proceed as given on next page.

CHECKING THE CONDENSER

If in doubt about the condition of the breaker points

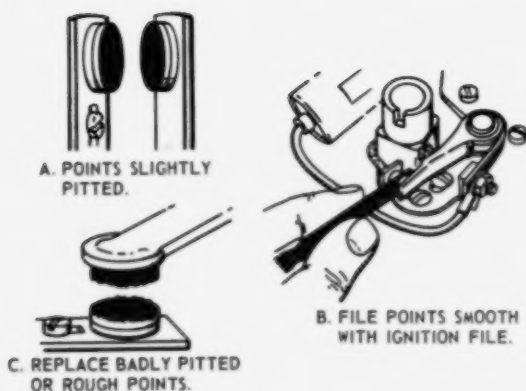


Fig. 57—Checking And Reconditioning Breaker Points

or ignition voltage, remove the condenser and test it with a condenser tester, if available (Fig. 58). The condenser should be tested for grounds, short, resistance, and proper capacity for system (per service manual specifications). Use instructions furnished with the tester units to make the tests.

REPLACING BREAKER POINTS

When replacing breaker points, be sure that you replace the condenser at the same time. Condensers are not expensive and you will be assured that a new one will operate properly.

To replace breaker points:

1. Remove breaker arm and spring (Fig. 59).

Disconnect the condenser lead and the breaker arm spring from the primary terminal.

If the breaker arm is separable from the breaker point bracket, pull it off.

Fig. 58—Testing The Condenser With A Condenser Tester

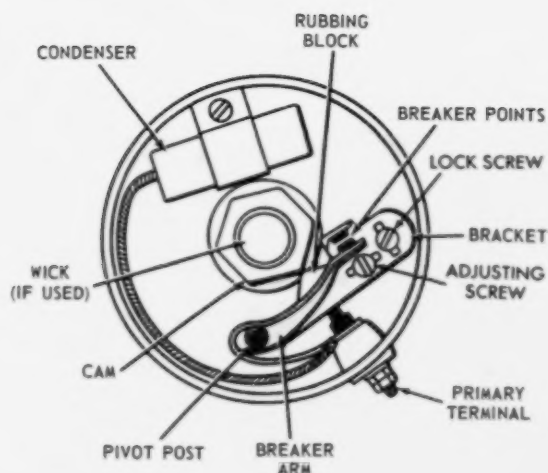
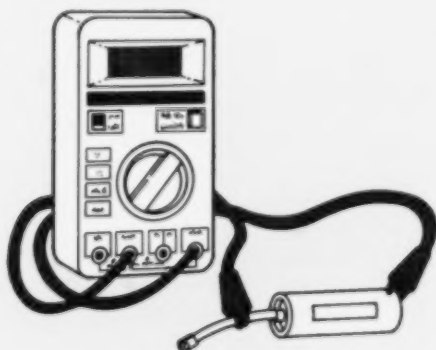


Fig. 59—Typical Mounting For Distributor Breaker Point Assembly

If the breaker arm is riveted to the stationary breaker point bracket, remove the bracket together with the breaker arm.

2. Clean and then lubricate the cam with special cam lubricant. Use a very small amount of lubricant about the size of a small match head. Distribute the lubricant around the cam. Petroleum jelly or multi-purpose grease or crankcase oil is not sufficient. They melt when hot or become stiff in cold weather. In either case, the breaker points may not function properly.

If the top of the cam has a wick (Fig. 59), apply a few drops of clean SAE 20 oil to the wick.

3. Remove the condenser (Fig. 59).

4. Install new condenser and breaker points in the reverse order of disassembly. Apply a drop of clean SAE 20 oil around the breaker-arm pivot post. Be sure all electrical connections are tight.

IMPORTANT: Never allow lubricant to get on the breaker point contacts.

Now we can adjust the breaker points.

ADJUSTING BREAKER POINTS

1. First check the alignment of the breaker points (Fig. 60). If points are misaligned, the results will be excessive burning, pitting, and uneven wear of points.

If necessary, loosen lock screw and adjust at adjusting screw (see Fig. 59).

2. Turn the engine crankshaft until the distributor cam opens the breaker points to their widest position (Fig. 61).



Fig. 60—Alignment Of Distributor Breaker Points

CAUTION: When cranking the engine, be sure the transmission is in park or neutral and the brakes are set. This will prevent the machine from moving and avoid injury to yourself and others nearby.

Crank the engine by "bumping" the starter, by turning the fan by hand (remove spark plugs to allow the engine to turn easier) or by using a heavy screwdriver in the flywheel housing to pry the flywheel (some engines have a slot or special rotating tool for this purpose). See your operator's manual for other suggestions.

Fig. 61—Breaker Points At Widest Position

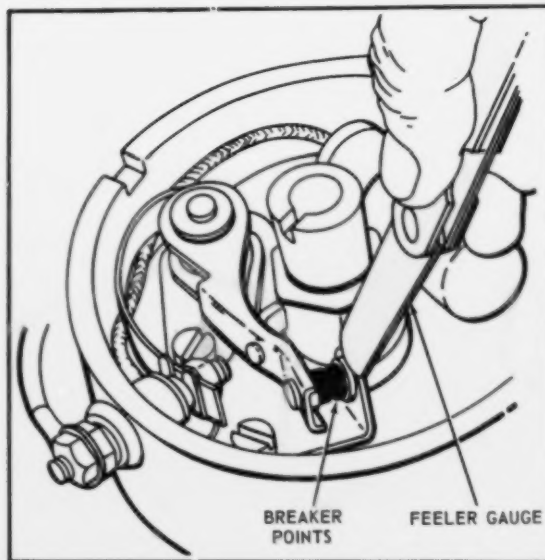
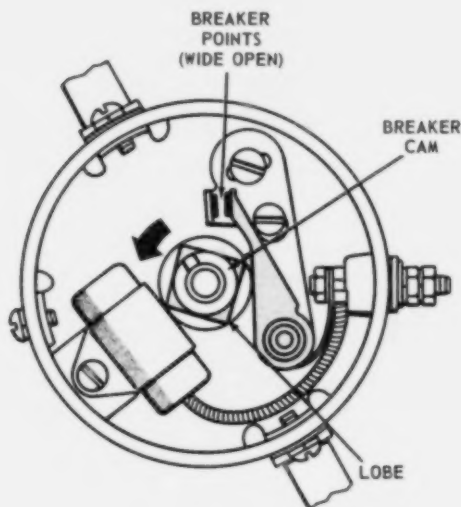


Fig. 62—Using A Feeler Gauge To Check Point Gap

If the cam lobe is close to opening the points, you might be able to turn the advance mechanism enough to open the points to their widest position.

3. Check the point gap for proper spacing using a blade-type feeler gauge (Fig. 62).

Select the proper thickness of feeler gauge (varies from .010 to .028 inch; 0.250 to 0.700 mm) per recommendations in your operator's manual.

Insert the gauge between the points. If the gap is correct, you should feel a slight drag on the feeler gauge as you pull it between the contact points.

If the gap is too tight or too loose, proceed with Step 4.

4. Loosen lock screw on the stationary point bracket (Fig. 63).

5. Adjust the points for proper spacing. An adjusting screw (Fig. 63) or screwdriver slot provides the means of adjustment.

If you set the points too close, they will rapidly burn and pit.

If you set the points too wide, they will cause a weak spark at higher engine speeds.

Improper gap will also affect the timing of your engine.

6. Lock breaker points into position with the lock screw (Fig. 63).

NOTE: Any change in point setting affects the ignition timing.

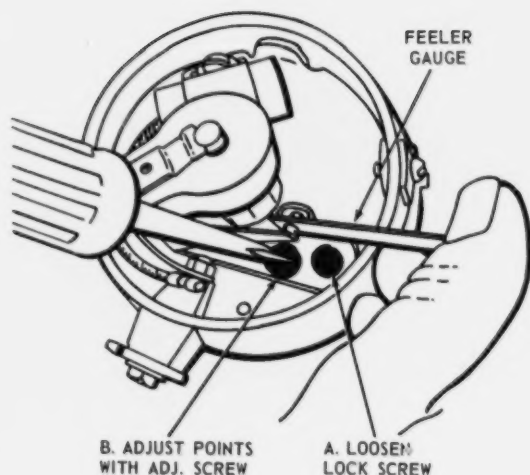


Fig. 63—Adjusting Breaker Point Gap

7. Recheck the gap and wipe the points clean with a strip of paper or clean cloth (Fig. 64). *Points must be absolutely clean. Any particle will cause rapid burning of points.*

By rechecking the gap, you can be assured that the gap wasn't changed when you tightened the locking screw.

An alternate way to check the gap on old points is shown in Fig. 65. This method is more accurate on worn points as it is not affected by rough point sur-

Fig. 64—Cleaning Contact Surfaces

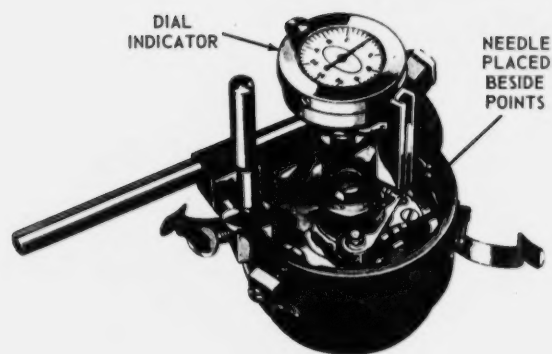
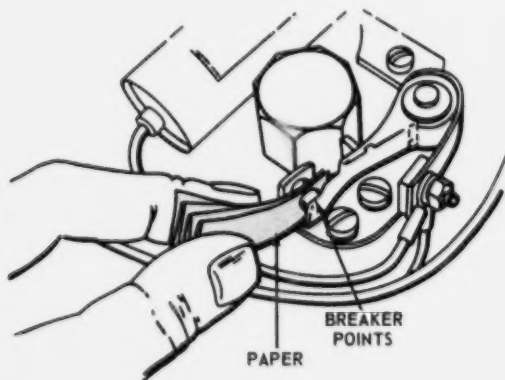


Fig. 65—Checking Point Gap With Dial Indicator (Alternate Method)

faces. Indicator is placed beside breaker arm as shown to measure how far it opens.

CHECKING CAM ANGLE (DWELL)

The *cam angle* is the number of degrees that the breaker cam rotates from the time the points close until they open again (Fig. 66). As the cam angle increases, the point gap decreases, and vice versa.

Too little cam angle can cause engine to misfire at high speed.

Too much cam angle allows the points to close for too long, causing burned points.

Use the dwell meter on a distributor tester (if available) to check the cam angle. Then adjust the points to the specified dwell angle.

If the cam angle reading on the meter varies more than two degrees, look for a worn drive shaft or bushings.

If the cam angle and point gap cannot both be set to specifications at the same time, check for these problems:

- Improper spring tension
- Wrong contact point assembly
- Worn breaker cam
- Points not following cam at high speeds
- Bent distributor drive shaft

Now we're ready to assemble the distributor.

8. Reassemble the distributor in the reverse order of disassembly. Be sure that the rotor does not come in contact with the condenser lead wire or it could short out the condenser.

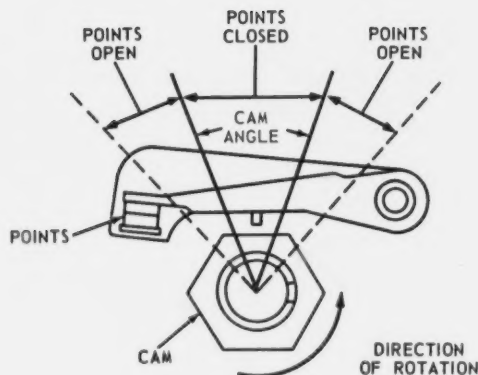


Fig. 66—Distributor Cam Angle (Dwell)

9. Check the condition of the wires leading to the spark plugs and coil. Be sure connections are tight, the nipples seal over the terminals and the insulation is not soft or cracked. Replace wires if they show damage.

Because you have replaced the points or readjusted them, you must check or retune the ignition. Remember we said that the breaker point gap affects timing.

TIMING THE IGNITION CIRCUIT

Two methods of timing are available:

- Breaker Point Method
- Timing Light Method

Of the two methods above, the *timing light method* is more accurate than the breaker point method. However, we will demonstrate both methods.

Timing Ignition By Breaker Point Method

To time the engine by this method:

1. Locate the timing marks on the engine flywheel or fan pulley (Fig. 67). Your operator's manual should tell you where they are and which ones to use. Usually there are several marks before and after TDC (top dead center). If the marks are difficult to see, mark over them with chalk or paint to make them more visible.
2. Remove distributor cap so that you will be able to see the distributor rotor rotate when you crank the engine. You will need to know the direction of rotation for step 9.
3. Remove or loosen No. 1 spark plug. If you loosen the spark plug two or three turns, you will be able to hear air escape when the No. 1 piston is on its com-

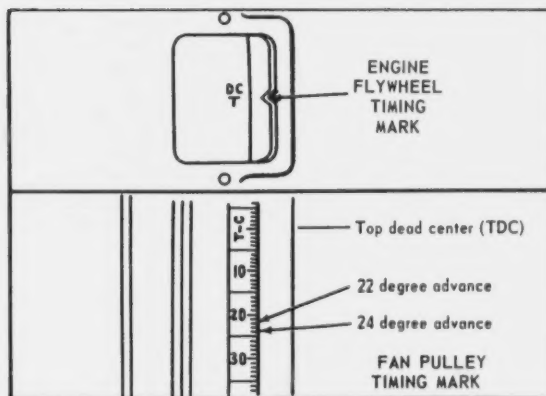


Fig. 67—Typical Engine Timing Marks (Spark-Ignition Engine)

pression stroke. If you have someone helping you, remove the plug and place your thumb over the spark plug hole so that you can feel the air pressure as the compression stroke begins.

4. Crank the engine until No. 1 piston starts its compression stroke. Step 3 describes how to determine when the compression starts.

CAUTION: When cranking or starting the engine, be sure the transmission is in park or neutral and the brakes are set. This will prevent the machine from moving and avoid injury to yourself or others nearby.

Crank the engine by "bumping" the starter, by turning the fan by hand (remove spark plugs to allow the engine to turn easier) or by using a heavy screwdriver in the flywheel housing to pry the flywheel (some engines have a slot or special turning tool for this purpose). See your operator's manual for other suggestions. (A special starter cable is sometimes available for engaging the starter while working close to the engine.)

Look for which way the distributor rotor turns as you crank the engine. You will need this information for step 9.

5. Place the distributor end of the coil high-tension wire $\frac{1}{8}$ -inch (3 mm) from the engine (Fig. 68). Turn ignition switch on. A spark will jump the gap as the distributor points start to open.

6. Continue to rotate the crankshaft until the proper timing marks appear aligned with the timing pointer. See your operator's manual to determine which markings to use.

If the spark jumps the gap when the proper timing marks are aligned, the timing is correct. Reassemble the distributor. Replace spark plugs and tighten.

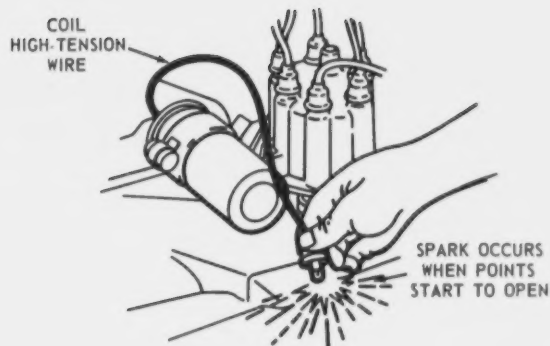


Fig. 68—Checking For When Distributor Points Start To Open

If timing is not correct, proceed with the remaining steps.

7. Reestablish proper positions of No. 1 piston and timing marks as described in steps 4 and 5.

8. Loosen clamps holding distributor to engine block (Fig. 69).

9. Turn the distributor body slowly in the direction the rotor normally turns (Fig. 69). You observed the rotation of the rotor in step 4. This procedure retards the time the breaker points open and makes sure the points are completely together.

10. Now, turn the distributor body slowly in the opposite direction until the points start to open and the spark jumps the gaps (see Step 5 above).

11. Tighten distributor clamps and reassemble distributor. The ignition is now timed.

12. Be sure the spark plugs are installed and properly tightened. Also, reconnect spark plug wires.

13. Start the engine to determine if it operates satisfactorily. If the engine is misfiring or backfires, you may have reconnected some of the spark plug wires incorrectly.

To check sequence of spark plug wires:

A. Identify which wire and distributor terminal leads to No. 1 cylinder. This connection should be correct since you just finished timing the engine with it.

B. Determine the firing order of the engine either from numbers appearing on the engine or from your operator's manual.

C. Remove all spark plug wires from the distributor except No. 1.

D. Insert spark plug wires in the distributor cap in the order that the cylinders fire. Proceed around the cap in the same direction in which the rotor turns.

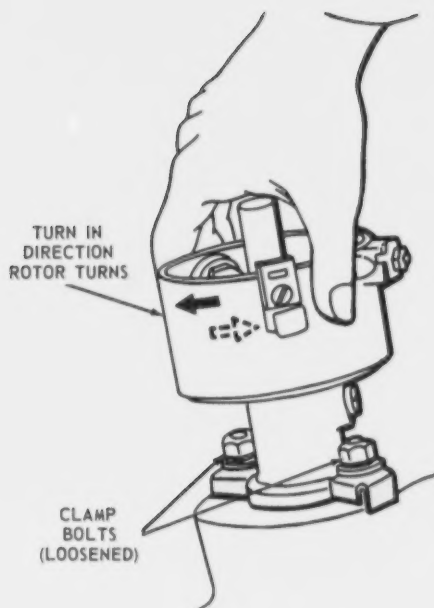


Fig. 69—Turning Distributor Body

14. The engine should now run properly. If it doesn't, something else may be wrong. Review the steps you performed when timing the engine; perhaps you did something incorrectly. If you can't determine what is wrong, see your local service shop.

Timing Ignition By Timing Light Method

To time the engine with a timing light:

1. Locate the timing marks on the flywheel or fan pulley (see Fig. 67) just as you did in the previous method. However, you will probably use a different mark—see the operator's manual.

2. Connect the timing light to the No. 1 spark plug and make any other connections recommended by the timing light manufacturer (see Fig. 70). Three types of timing lights are available:

- Two-Wire Leads
- Three-Wire Leads
- 110-Volt Powered

The TWO-WIRE TYPE has one lead connected to the No. 1 spark plug and the other to a ground connection.

The THREE-WIRE TYPE is connected with one lead to the No. 1 spark plug and the other two to the battery terminals.

The 110-VOLT TYPE has a lead which is connected to the No. 1 spark plug and the power cord plugs into a 110-volt receptacle.

Be sure to read the instructions included with the tim-

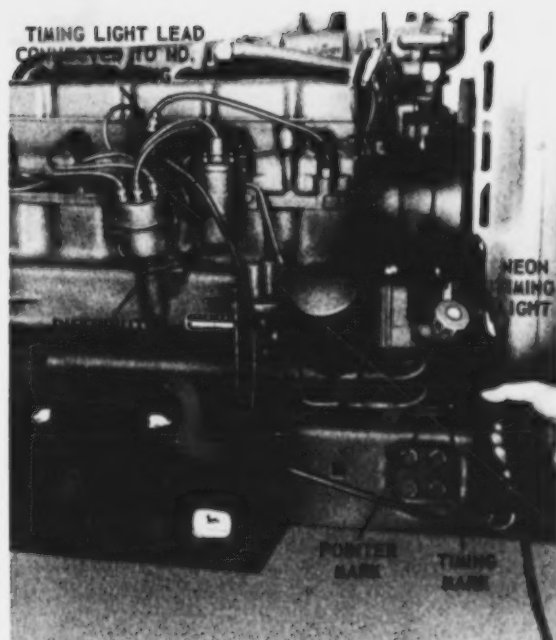


Fig. 70—Timing The Distributor With A Timing Light

ing light so that you make the proper connections.

3. Determine the correct engine operating speed for making timing adjustments according to your operator's manual.

4. Chalk the proper timing mark so that it is easy to see.

5. Start the engine and adjust it to the proper speed.

6. Aim the timing light (Fig. 70) at the marking or pointer near the flywheel or crankshaft fan pulley (wherever the timing marks appear).

CAUTION: Be careful that you don't get your hand or the timing light leads caught in any drive belts or the fan blades.

Be sure you aim the timing light so that it is aligned with the pointer mark and the centerline of the crankshaft (Fig. 71). This will assure you of a correct reading.

If the proper timing mark doesn't align exactly with the pointer, proceed with the following steps.

7. Loosen clamps holding distributor (Fig. 70).

8. Turn distributor body slowly back and forth until timing mark is exactly opposite the pointer.

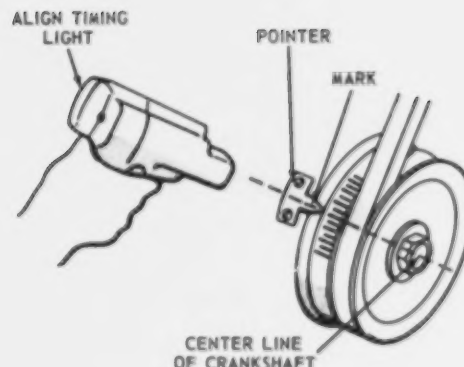


Fig. 71—Be Sure To Align Timing Light With Pointer Mark And Center Of Crankshaft

9. Tighten distributor clamps and remove timing light from engine.

10. Recheck idle speed, as timing can affect engine speed.

SERVICING ALTERNATOR (OR GENERATOR) AND STARTING MOTOR

The alternator (or generator) and starter will normally require little attention. But it is important that they receive service when required or you will have trouble starting your engine and these components may become damaged.

OPERATION OF ALTERNATOR, GENERATOR, AND STARTER

The **alternator** (a.c. charging circuits) operates continuously while the engine is running (Fig. 72). A regulator controls the alternator output as required to charge the battery or supply other electrical components on the engine or machine with power. The alternator is more efficient than the older style generator and it produces an alternating current which flows back and forth. This current must be "rectified" (made to flow in one direction) to be usable by the electrical systems. This is done by electronic "check valves" called diodes within the alternator.

The alternator has two advantages over a generator:

- Produces a higher output at lower engine speeds
- Simple construction requires less maintenance

The **generator** (d.c. charging circuits) (Fig. 73) serves the same purpose as the alternator. But, because it is less efficient, it is found mostly on older machines. The generator has been replaced by the alternator on most modern engines.



Fig. 72—Alternator (A.C. Generator)

The **starting motor** (Fig. 74) engages the flywheel when the engine is to be cranked for starting. As soon as the engine starts, the starting motor disengages. Running the starter without pause for more than 20 or 30 seconds will cause overheating and damage to the starter. It is designed to handle heavy loads for short periods of time only.

Most alternators do not require any periodic service except to check electrical connections and belt tension. However, read the following alternator and voltage regulator precautions to avoid damaging these components.

If your alternator, generator or starting motor requires more service than is given in the following procedures, take it to your local service shop.

Precautions For Alternator and Voltage Regulator

Disconnect the battery ground strap from the battery when working on or near the alternator or regulator.

Fig. 74—Starting Motor and Solenoid

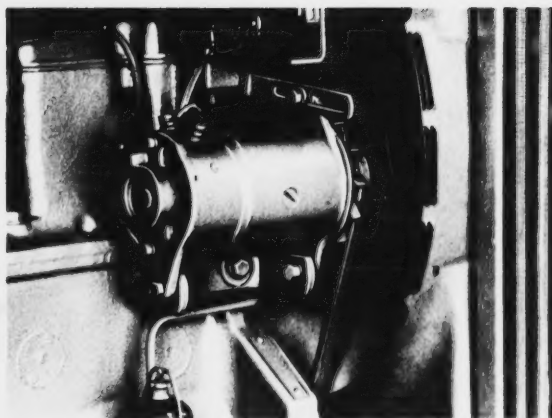


Fig. 73—D.C. Generator

This will prevent damage that might occur if the terminals are accidentally shorted.

When the batteries are connected, observe the following precautions. Failure to observe them will probably result in damage to the alternator, regulator or both.

1. **NEVER ATTEMPT TO POLARIZE THE ALTERNATOR OR REGULATOR.** Never ground a terminal or connect a jumper wire to any alternator terminals.
2. If electrical problems are encountered, **before** disconnecting the battery or alternator from the circuit, check for proper polarity. If polarity was incorrect the alternator has probably been seriously damaged. Have it repaired by a qualified service shop.
3. Before installing a battery or alternator, **BE SURE OF PROPER POLARITY.** Turn off all switches and accessories. Then, before connecting the battery ground strap, momentarily touch it to the battery post. No sparks should occur. If there are sparks, recheck all connections and installation procedures.
4. The alternator field terminal or the field circuit between the alternator and the regulator must never be grounded under any circumstances.
5. The alternator output terminal must never be grounded under any circumstances.
6. **NEVER** disconnect or connect any alternator wires with batteries connected or with alternator operating. Do not operate the alternator on open circuit. The high voltage resulting from open circuit operation will result in damage to the alternator, regulator, or electrical system.
7. Always connect additional batteries to each other in the correct polarity: **POSITIVE to POSITIVE and NEGATIVE to NEGATIVE.**
8. **IMPORTANT:** Disconnect cables from positive battery terminals when charging batteries.



Fig. 75—Adjusting Generator Belt Tension

SERVICING THE ALTERNATOR (OR GENERATOR) AND STARTER

The generator and starter require similar service; therefore, we will cover both components later with the same discussion.

Checking Alternator (or Generator) Belt Tension

Every 250 hours or as recommended, check the alternator (or generator) belt tension (Fig. 75).

Flex the belt with a firm push midway on the side of the belt and measure with a ruler. If belt tension is specified in pounds (kg) rather than inches (mm) of flex, use a spring scale or belt tension gauge to measure tension.

If necessary, loosen the mounting bolt as shown and adjust the belt. Then tighten the bolt and recheck the tension.

NOTE: When a new belt is installed, always recheck the tension after a few hours of operation. This is when the initial "stretch" takes place.

Also note the condition of the belt. Excessive wear, fraying, or slack mean the belt should be replaced with an exact duplicate from your dealer.

IMPORTANT: Be sure belt is not too tight as it may wear out alternator (or generator) bearings faster. A small amount of flex is needed in the belt.

Check the condition of the generator and starter every 500 hours or when your operator's manual recommends attention. Almost all generators and starters have sealed bearings so that lubrication is not required. However, some have oil cups for bearing lubrication every 250 hours.

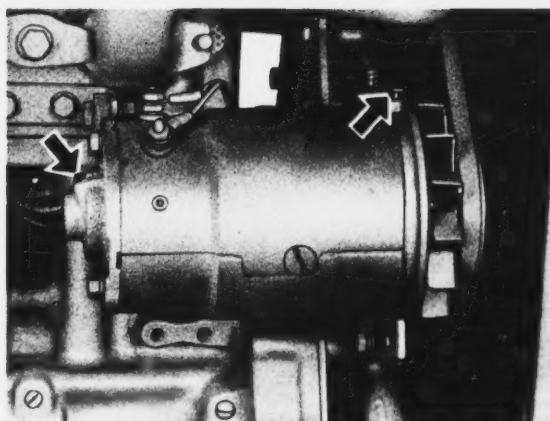


Fig. 76—Lubricating Generator Oil Cups

Lubricating Generator Oil Cups (If Used)

Every 250 hours or as recommended, add specified engine oil to front and rear oil cups on generator (Fig. 76). Most generators are sealed, but some have oil cups as shown. Only 8 or 10 drops of oil are required. *Do not over lubricate!* This can damage inner parts more than lack of lubricant.

Also check for excessive dirt around generator housing and wipe off if necessary.

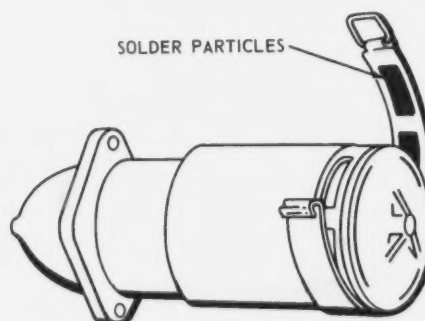
Servicing Generator And Starter

To service the generator and starter, proceed as follows.

Tools and Materials Needed

1. Screwdriver
2. Open-End Wrenches (inch or metric, as required)
3. Clean Cloth and Solvent (not gasoline)

Fig. 77—Overheated Starter Or Generator



Removal And Inspection

1. Remove the generator or starter to inspect it.
2. Wipe dirt and grease from the housing. Use a cloth dampened with solvent if necessary.
3. Remove cover band or end plate, whichever provides access to the brushes and commutator.
4. Inspect for signs of overheating. If solder has been thrown against the band (Fig. 77) or against the inside of the housing, the unit requires expert repair. Take it to a service shop.
5. If other problems are evident, take one of three steps:
 - a. Take the generator or starter to a service shop.
 - b. Follow servicing recommendations in the technical service manual for that engine.
 - c. Follow servicing procedures in Fundamentals of Service, ELECTRICAL SYSTEMS.

Polarizing Generator

If any wire leads were disconnected from the starter or generator while servicing, polarize the generator before starting the engine. See the operator's manual for details. Reverse polarity can create high current and damage the ignition system.

On externally grounded generator:

1. Reconnect the proper wires and terminals.
2. Touch short jumper wire (Fig. 78) momentarily between the terminals marked "BAT" and "GEN" (sometimes marked "ARM").

On internally grounded generator:

1. Momentarily touch the ends of the "BAT" wire and "FLD" wire together (Fig. 79).
2. Reconnect proper wires and terminals.

NOTE: A flash or arc will be noted when the lead is removed in either case. This polarizes the generator. On high-voltage generators, insulate the brushes. Failure to polarize the generator will result in a burned-out generator if the polarity is wrong.

IMPORTANT: Do not attempt to polarize an ALTERNATOR system. Alternators do not require polarization and any attempt to do so will damage the alternator.

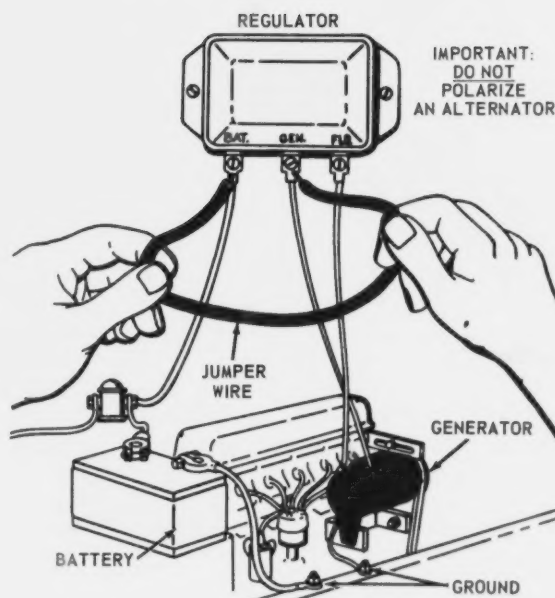
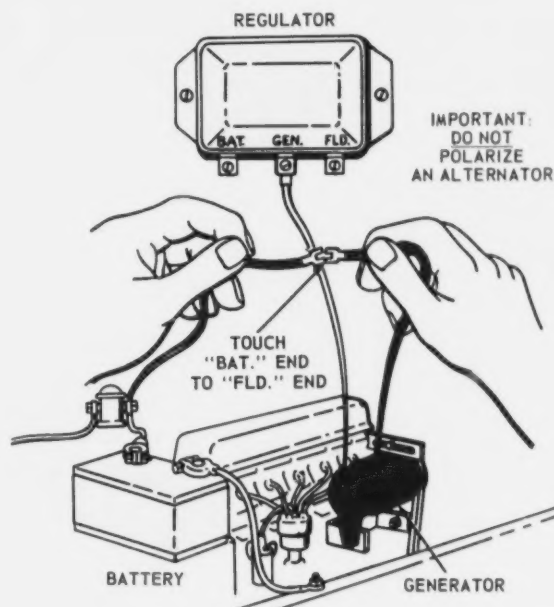


Fig. 78—Polarizing Externally Grounded Generator

Fig. 79—Polarizing Internally Grounded Generator



WATCHING GAUGES DURING OPERATION

When operating a machine, glance at the electrical gauges from time to time. They will tell you if the electrical system is charging properly.

The voltmeter shown in Fig. 80 tells the operator if the battery is being charged and also tells the charged condition of the battery itself. Once the engine is running, the voltmeter needle should stay in the white "normal" range.

Indicator lights are used on some machine consoles. These glow to warn of a low charging rate.

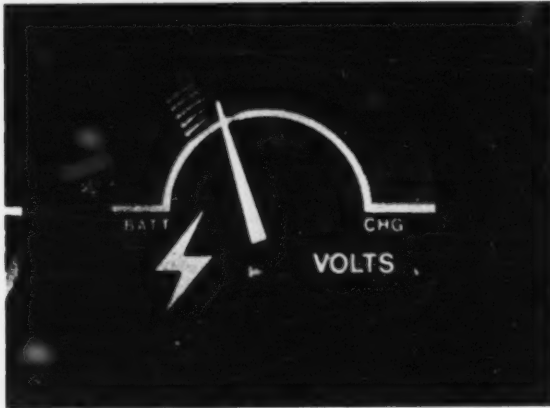


Fig. 80—Voltmeter Tells Battery Charge And Condition

When starting the engine, the electrical indicator lights will glow, but they should go out after the engine has been running for a few seconds.

CHAPTER QUIZ

1. Which of the following are results of poor engine timing?

- ___A. Burned valves
- ___B. Worn breaker points
- ___C. Excessive oil consumption
- ___D. Excessive fuel consumption

2. True or false? "The condition of the spark plugs affects timing."

3. What are the *three* basic circuits in an engine electrical system?

1. _____
2. _____
3. _____

4. What causes a dirty battery to lose its charge?

5. What makes battery charging a potential safety hazard?

6. True or false? "An engine that runs at fast speeds, heavy loads and hot temperatures, requires a hotter spark plug."

7. Which of the following are *not* causes of spark plug failures?

- ___A. Burned breaker points
- ___B. Cracked distributor cap
- ___C. Cracked plug insulation
- ___D. Carbon deposits on the electrodes
- ___E. Incorrect spark plug gap

8. What is a sure sign that a generator or starter has overheated?

9. (Fill in the blank.) After performing electrical service on the generator, always _____ it before starting the engine.

10. Match the items below with their proper description:

- ___A. If you set the _____ 1. They will cause a weak
breaker points spark at higher speeds.
too close ...
- ___B. If you set the _____ 2. They will rapidly burn
breaker points and pit.
too wide ...

7

Power Trains



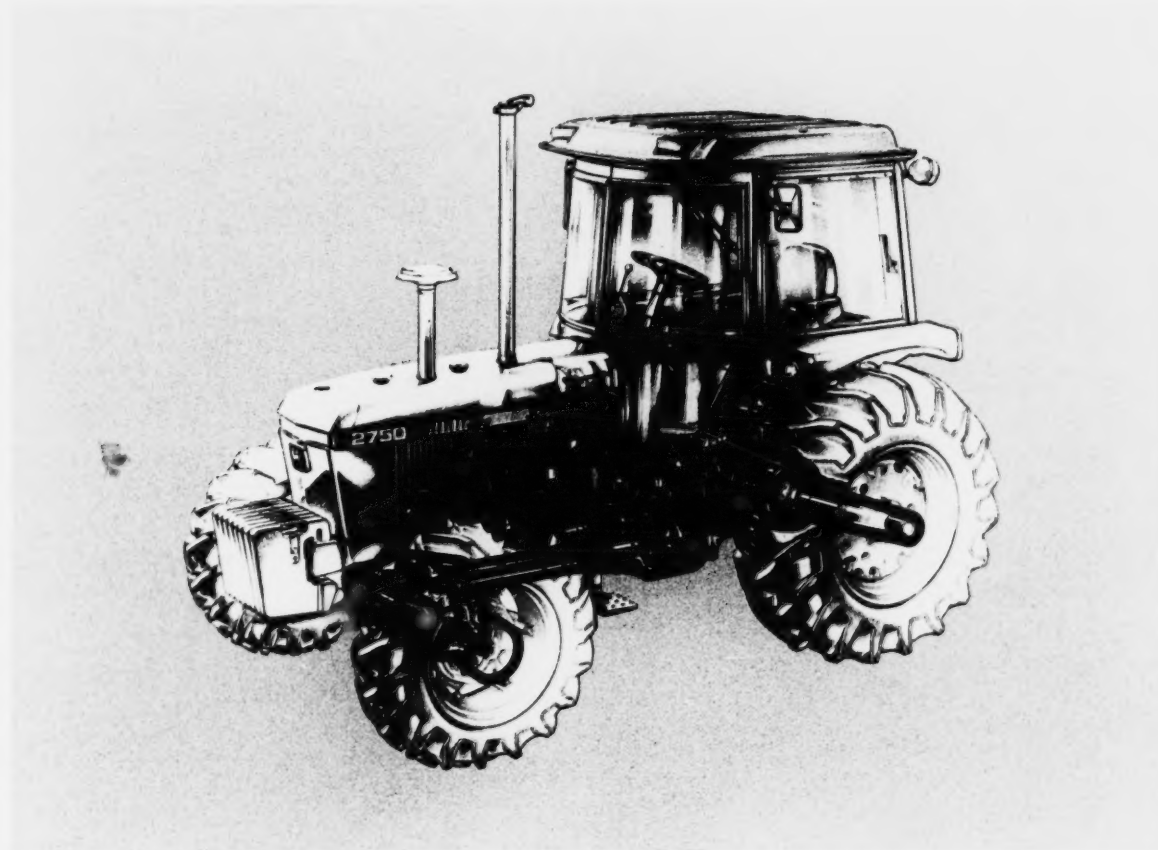


Fig. 1—Power Train In Farm Tractor

INTRODUCTION

The power train (Fig. 1) has to absorb tremendous forces in today's farm machines. These components also operate under severe conditions: from the freezing cold of winter to the searing heat of summer—and from engine-staggering loads to rough, start-and-stop operation.

Because the clutch, transmission, and final drives receive such severe use, important periodic maintenance is required to provide transmission of power for the life of the machine (Fig. 2).

The lubricant used in the power train, whether it is hydraulic fluid or gear oil, becomes contaminated by dust, rust, moisture and metal particles. All of these elements can cause severe damage to gears, bearings, and valves when the power train maintenance is neglected.

Because the transmission lubricant is so important, let's discuss it first.

SELECTING TRANSMISSION LUBRICANTS

Three basic types of transmissions are used today. Each requires specific types of lubricants. Below is a description of each type of transmission and its lubrication requirements.

- **Sliding gear transmissions** require *gear oils* to provide lubrication under extreme pressure conditions.
- **Automatic transmission** (including torque converters and hydrostatic transmissions) require *automatic transmission fluid* to provide a medium to transmit power, lubricate and transfer heat.
- **Hydraulic assist transmissions** require *transmission-hydraulic fluids* to provide a medium to transmit power, lubricate and transfer heat to both the transmission and hydraulic system of the machine (Fig. 3).

Let's look at each of these transmission lubricants in more detail.

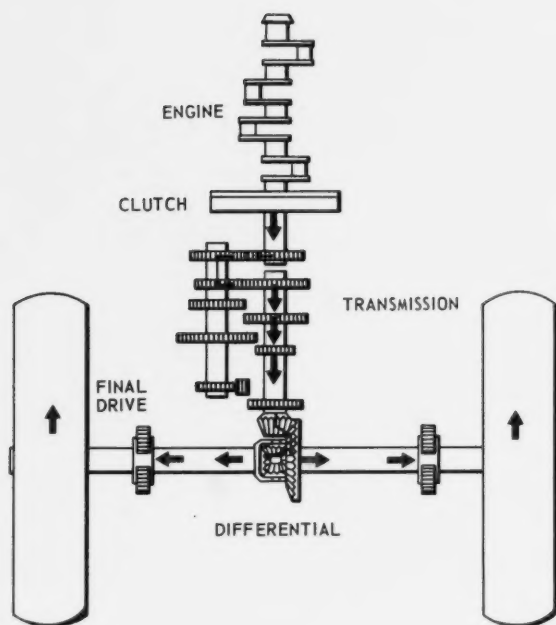


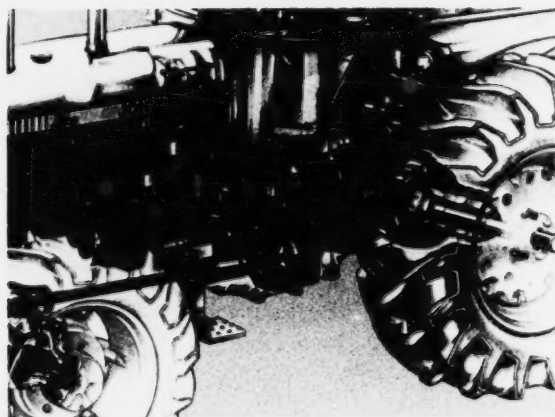
Fig. 2—Parts of A Power Train

GEAR OILS

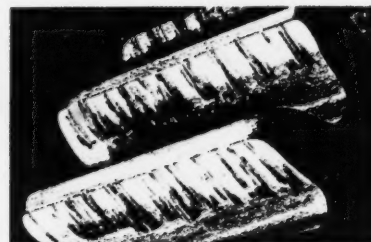
The relatively small gears used in today's power trains result in higher loads and more friction between meshing gears. This makes lubrication more critical. Unless a good film of lubricant is maintained between the meshing gear teeth, they will show excessive wear and scoring (Fig. 4).

In spur gear units (Fig. 5), where tooth pressures are relatively light, a simple gear oil is often adequate. However, special gears, such as spiral bevel and

Fig. 3—Transmission-Hydraulic Oil Reservoir



NORMAL WEAR



SCORING WEAR

Fig. 4—Normal Gear Wear and Scoring Wear

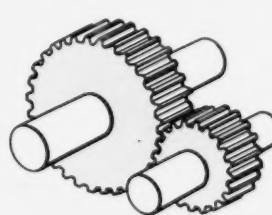
worm gear units (Fig. 5) can wear very rapidly unless the correct gear oil is used.

For these higher loads, the gear oil must have special "anti-friction" and "anti-weld" agents. Oils containing these additives are known as *extreme pressure* or *hypoid* lubricants.

To select the proper gear oil you must know:

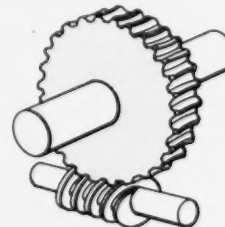
1. *Viscosity requirements*
2. *Service classification requirements*

Fig. 5—Gear Oils Must Match The Gear Load



SPUR GEARS—

Lower gear loads and less rubbing. Standard gear oils are often adequate.



WORM GEARS—

Higher gear loads and more rubbing. Special gear oils are often needed.

Viscosity Classification

The Society of Automotive Engineers (SAE) gear oil classification is based on the viscosity of an oil.

While the SAE numbers of gear oils are higher than the SAE numbers of engine crankcase oils, gear oils are not necessarily that much higher in viscosity. To avoid confusion, higher numbers are assigned to gear oils (Fig. 6). For example, SAE 80 gear oil actually has about the same viscosity as SAE 20 engine oil.

Multi-grade gear oils are presently available from some suppliers in grades of SAE 75/80 and SAE 80/90.

Some manufacturers recommend engine crankcase oils for use in standard transmission service, while some transmissions may use SAE 50 engine oil as an alternate for SAE 90 gear oil. As a result of this, some gear oil containers are marked SAE 50-90 indicating that the viscosity requirements of SAE 50 engine oil are also met.

Service Classification

The American Petroleum Institute (API) designates gear lubricants by the types of service for which they may be suitable. *This is not a rating of performance.*

API GL-1 oil is the lowest service, adequate for lower gear speeds and pressures, while GL-5 oil is for the hardest service.

As the "GL" number rises, so does the type of service.

Fig. 6—Higher SAE Viscosity Numbers Are Assigned To Gear Oils (To Avoid Confusion)

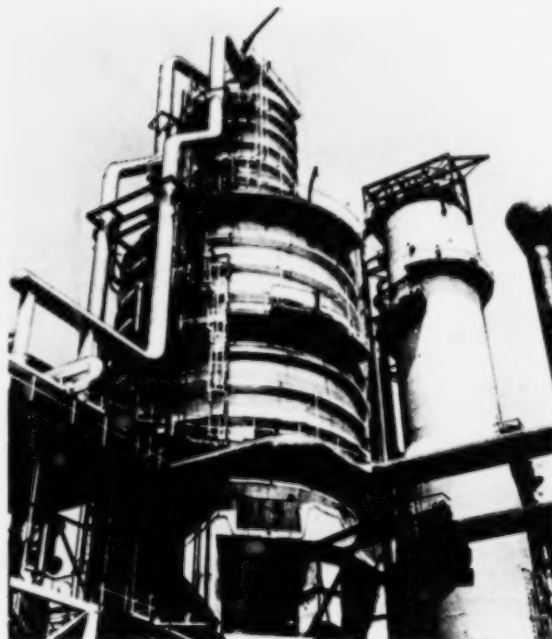
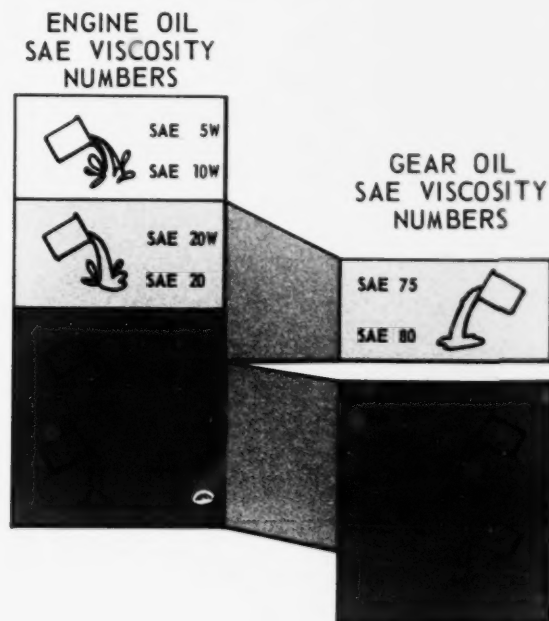


Fig. 7—Distillation Plant For Distilling Crude Oil

For example, GL-5 oil is rated for harder service than GL-4.

Lubricants indicated for API Service GL-4 and GL-5 are applicable for use in non-automatic transmissions and final drives, and are generally available locally.

API Service GL-6 is an obsolete designation which may have been specified for some older machines. If so, consult your machine dealer or a reputable oil supplier for the proper substitute.

Refer to your operator's manual for recommended gear oils—the suggested viscosity and service classification should be designated.

AUTOMATIC TRANSMISSION FLUID

Inside an automatic transmission, the lubricant must perform specific functions under severe conditions. These are:

1. Protect heavily-loaded helical and spiral gears with an oil film cushion.
2. Perform as a non-foaming fluid in transmitting power.
3. Operate as a hydraulic fluid between -30° and $+300^{\circ}\text{F}$ (-35° and 150°C).
4. Act as a wet clutch and transmission lubricant to provide smooth, silent engagement, without slipping.
5. Resist oxidation under conditions of heat and aeration, while at the same time be compatible to all met-

als, rubber seals, gaskets, adhesives, facings, and liners in the system.

Automatic transmission fluids are designed to perform under a variety of conditions. Because of this, three popular types of fluids are used in most automatic transmissions today:

- *Type F (Ford Motor specification)*
- *DEXRON II (General Motors specification)*
- *Detroit Diesel Allison C-3*
- *John Deere Hydrostatic Fluid*

Do not mix these fluids. Although these fluids are physically compatible, their built-in frictional properties are different to meet different transmission design requirements. Mixing alters the properties of the fluids and should be avoided. Follow the machine manufacturer's recommendations in selecting fluids.

Some special components may require different qualities from an automatic transmission fluid. Torque converters and hydrostatic transmissions are among these.

Torque Converter Fluids

Automatic transmission fluids, Type A and Suffix A, have proven satisfactory for torque converters in heavy-duty trucks, buses, and off-the-road machines.

More recently, the specification has been replaced by DEXRON II from General Motors, and Type F from Ford Motor.

However, torque converters may require different qualities from an automatic transmission fluid.

Hydrostatic Drive Fluids

Hydrostatic drives can use automatic transmission fluids, but may require different qualities in the fluid.

Always follow the exact fluid recommendations in the machine operator's manual.

TRANSMISSION-HYDRAULIC FLUIDS

Some farm and industrial manufacturers have designed machines with a common reservoir for both the transmission and hydraulic systems (Fig. 8). This means that the same lubricating fluid has to serve the gear train as well as the precision hydraulic system.

This requires special fluids, and these have been developed:

- *John Deere Hy-Gard Fluid*
- *International Harvester Hy-Tran Fluid*
- *Allis-Chalmers Power Fluid 821*
- *Case TCH and TFD Fluids*
- *Ford M2C53-A and M2C134-A Fluids*

These fluids are referred to as *four-way oils* because of the wide range of services they must perform.

Their key properties are:

1. Have high oxidation stability for long life and protection.
2. Have low pour point for low temperature service, particularly during cold starting.
3. Have high viscosity index for best viscosity under various operating temperatures.
4. Contain extreme pressure additives for increased load carrying and wear protection under heavy and shock loads.
5. Contain rust and corrosion inhibitors.
6. Are compatible with all types of seals.
7. Contain foam suppressors.

Some fluids which serve as transmission-hydraulic fluids also operate wet brake or wet clutch systems and require additives to control clutch or brake chatter.

While no transmission-hydraulic fluid will fully meet each specific need for every machine, products are available which will meet the service demands in any one machine for which these oils are specified.

Always use the oil specified by the manufacturer. Through testing, he has determined which oil will give the best service in his machine and his own special designs.

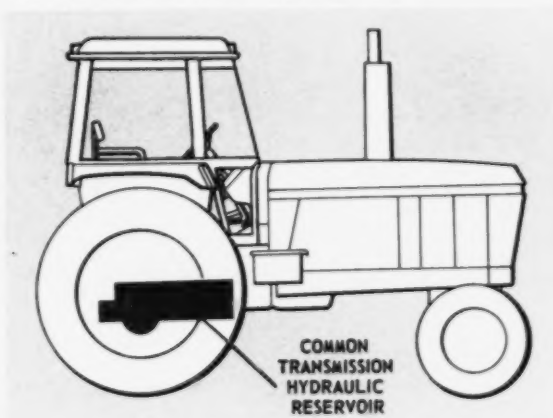
KEEPING TRANSMISSION FLUIDS CLEAN

Good lubricants, which come in cans or barrels, are delivered clean and free from contaminants. It is generally after the containers are opened or stored that trouble develops.

When opening a can or barrel, **BE SURE** that the area around the opening is completely free of dust, dirt, lint, or water. *If a container, tunnel, or hose is required to fill the system, be sure that it is spotless.*

When possible, always store barrels indoors, or at least under cover, and be sure the bung is tight. If

Fig. 8—Transmission-Hydraulic Systems



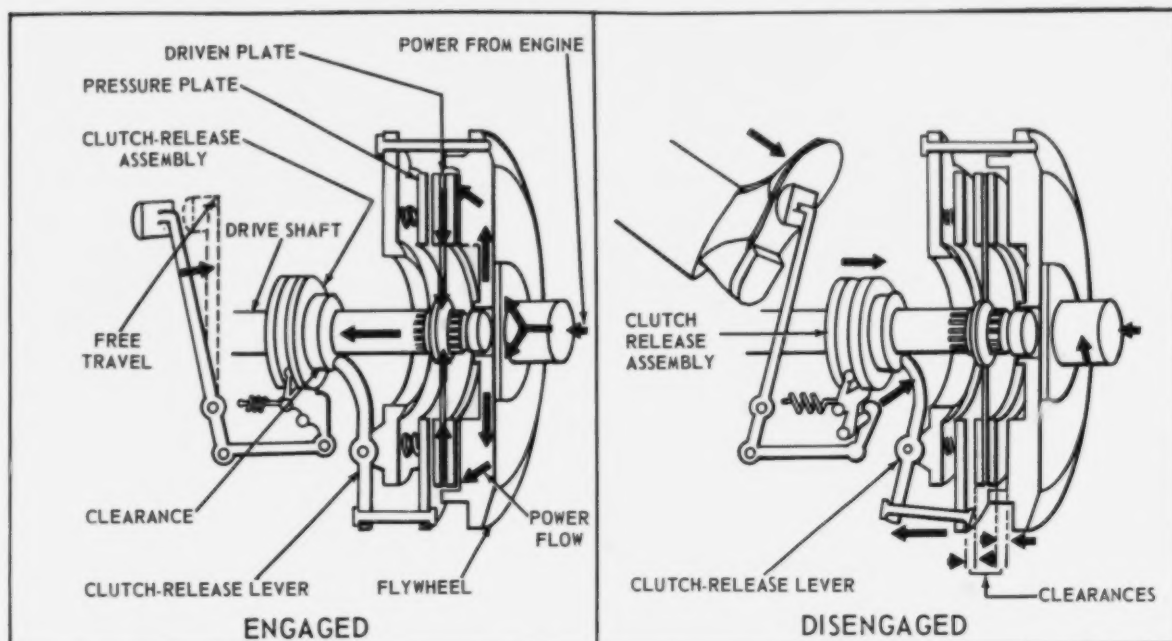


Fig. 9—Operation Of Standard Dry-Disk Clutch

barrels are stored in the sun without a tight bung, the fluid will expand forcing some air from the bung. Then as the fluid cools off, the fluid contracts, drawing rain, dew, or other moisture into the barrel and fluid.

The harmful effects of water in lubricants have already been discussed (Chapter 4). For this reason, keep the bungs in barrels as tight as possible, and tip the barrels so that water cannot collect around the bung.

OPERATION OF POWER TRAINS

To help understand why maintenance is important, we will briefly look at how the various power trains work.

Operation of the following components will be covered:

- Clutch
- Mechanical transmission
- Hydraulic assist transmission
- Hydrostatic drive
- Torque converter
- Differential
- Final drives
- Power take-off

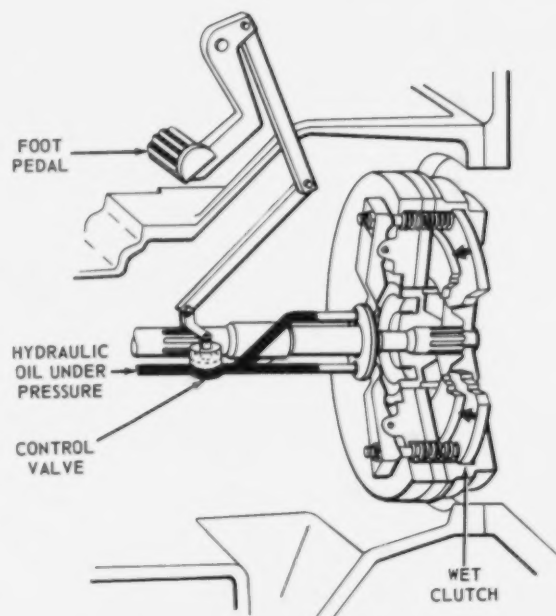


Fig. 10—Operation Of Hydraulic Clutch

OPERATION OF CLUTCH

The clutch provides the means of disconnecting the engine from its load while starting, shifting or idling. In Fig. 9 you can see how the standard dry clutch, found on most machines, operates.

In the *engaged* position, the pressure plate provides pressure against the clutch plate and forces the plate against the flywheel. Power is transmitted from the engine through the flywheel and clutch plate to the drive shaft or transmission input shaft.

The clutch is *disengaged* by applying pressure on the pedal which pushes the clutch release assembly against the release levers. The levers pull the pressure plate away from the clutch plate so that the clutch plate is no longer forced against the flywheel. Now the flywheel and pressure plate are free to rotate independently of the clutch plate and drive shaft.

Notice that in the engaged position, there is clearance (usually 1/16 to 3/16 inch; 1.6 to 4.8 mm) between the clutch release bearing and the clutch release levers. This is to allow for wear of the clutch plate facings.

As the facings wear, the release levers move closer to the clutch release bearing until, eventually, there is no clearance. Adjustment must then be made or the release levers will press continuously on the clutch release bearing and pressure will be reduced on the clutch plate.

This will cause the clutch release bearing to fail prematurely. And the clutch will slip also—resulting in a burned clutch and rapid facing wear.

To maintain this necessary clearance between the bearing and the release levers, the clutch pedal free travel must be maintained.

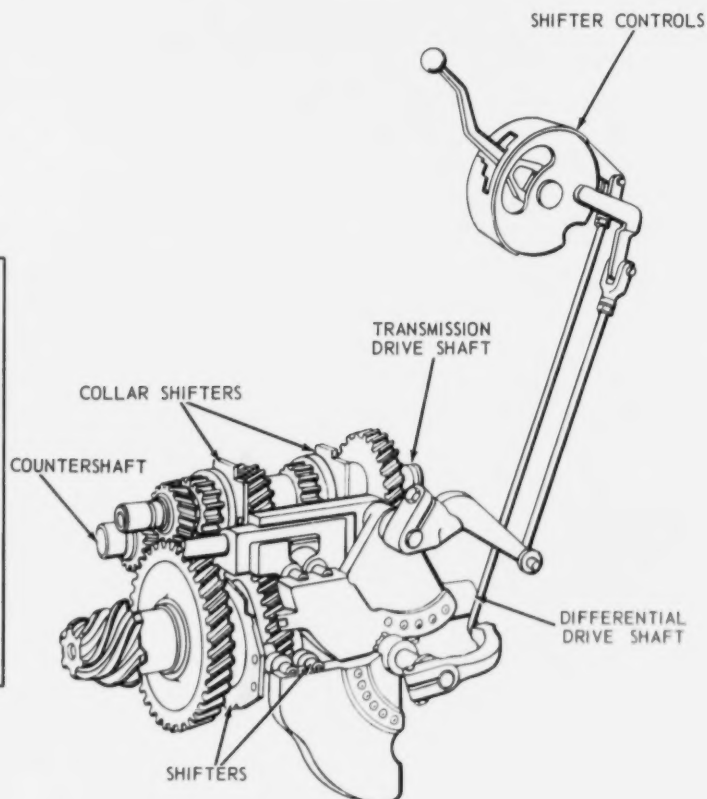
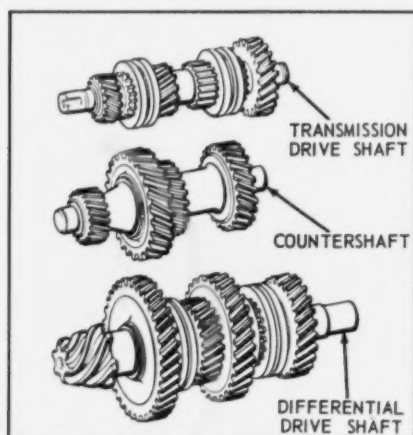
The free travel of the pedal indicates whether or not the proper clearance is present (Fig. 9, left). The less free travel of the pedal—the less clearance between the clutch release parts. Too much free travel, however, can prevent the clutch from disengaging completely which will cause difficult shifting of the transmission and overheating of clutch plate. We will describe how to adjust free travel later.

Note that the standard clutch is a *dry* disk type and that no lubricant is found in the clutch compartment (except for the grease fitting to the release bearing). Because the clutch operates by friction, the disks and plates must be kept perfectly dry.

Operation Of Hydraulic-Type Clutch

The hydraulic clutch (Fig. 10) is similar to the standard clutch except that the clutch plate operates *wet* in a transmission fluid and the clutch is engaged and disengaged hydraulically.

Fig. 11—Mechanical Transmission In A Complete Power Train



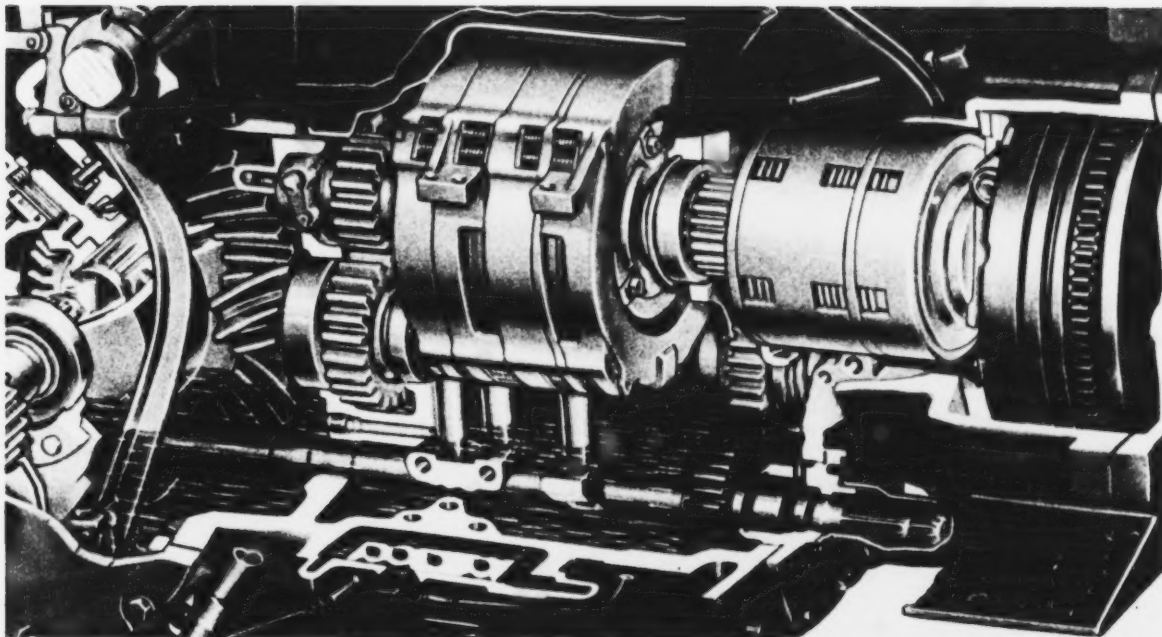


Fig. 12—Hydraulic Assist Transmission In A Complete Power Train

Hydraulic clutches don't normally require free travel or clearance adjustment.

OPERATION OF MECHANICAL TRANSMISSION

The mechanical transmission is a train of gears that transfers and adapts the engine power to the drive wheels of the machine.

The transmission does two jobs:

- 1) *Select speed ratios for various travel speeds.*
- 2) *Reverses the travel of the machine.*

The transmission can also power a special drive such as a PTO (power take-off).

Normally the transmission is located to the rear of the engine and clutch and in front of the differential or ring gear (Fig. 11).

Mechanical transmissions are of three major types:

- **Sliding Gear**
- **Collar Shift**
- **Synchromesh**

The **SLIDING GEAR** transmission has two or more shafts mounted in parallel or in line, with sliding spur gears arranged to mesh with each other and provide a change in speed or direction.

The **COLLAR SHIFT** transmission has parallel shafts with gears in constant mesh. Shifting is done by locking free-running gears to their shafts using sliding collars (see Fig. 11).

The **SYNCHROMESH** transmission also has gears in constant mesh. However, gears can be selected without clashing, by synchronizing the speeds of mating parts *before* they engage.

In all three cases, the transmission is shifted by hand or foot. So we call them *mechanical* transmissions.

The gear train for all these transmissions normally operates in a bath of gear oil. For special lubrication, oil sprays or feeder lines from oil pumps are sometimes used.

OPERATION OF HYDRAULIC ASSIST TRANSMISSION

The *hydraulic assist transmission* (Fig. 12) is a train of gears which can be shifted without interrupting the flow of power.

The gears are kept in constant mesh while two or more hydraulic clutches control the flow of power "on the go."

The parts work together as follows:

- **Hydraulic clutches—control the power flow**
- **Gear train—transmits the power flow**

When the operator shifts gears, hydraulic oil engages the clutches that route power to the selected gears.

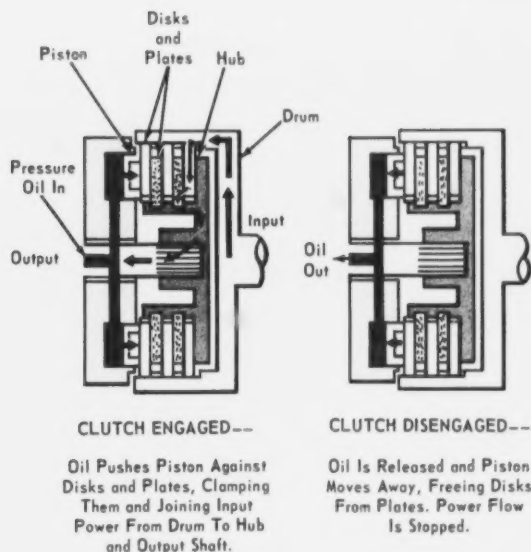
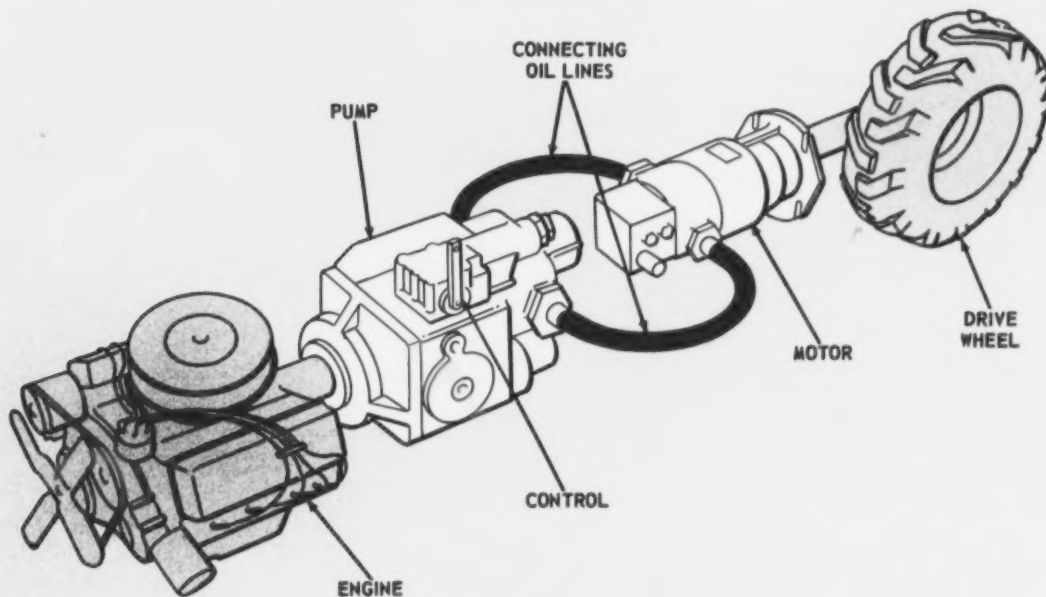


Fig. 13—Hydraulic Clutches Control The Power Flow In Hydraulic Assist Transmissions

A *hydraulic clutch* is normally an alternating pack of friction disks and plates (Fig. 13).

The clutch is *engaged* when pressure oil is sent to push the piston against the disks and plates, clamping

Fig. 14—Hydrostatic Drive In A Complete Power Train



them together. The disks are splined to the drum, while the plates are splined to the hub. As a result, input power through the hub is sent on through the hub to the output by the engaged clutch.

The clutch is *disengaged* when oil pressure is released and the piston moves away from the clutch pack. This frees the disks from the plates and the power flow is stopped. Spring action or oil pressure on the other side of the piston may be used to help release the disks and plates.

This hydraulic clutch unit replaces the standard clutch used on mechanical transmissions.

The *gear train* is usually either a *countershaft* or a *planetary* unit which feeds power to the output or drive wheels.

The gear train normally operates in an oil bath. This oil is usually the reservoir for the hydraulic circuit which operates the clutch units, so special transmission-hydraulic fluid must be used.

OPERATION OF HYDROSTATIC DRIVE

The *hydrostatic drive* is an automatic fluid drive which uses fluid under pressure to transmit engine power to the drive wheels of the machine.

Mechanical power from the engine is converted to hydraulic power by a pump-motor team (Fig. 14). This power is then converted back to mechanical power for the drive wheels.

The hydrostatic drive can function as both a clutch and transmission. The final gear train can then be

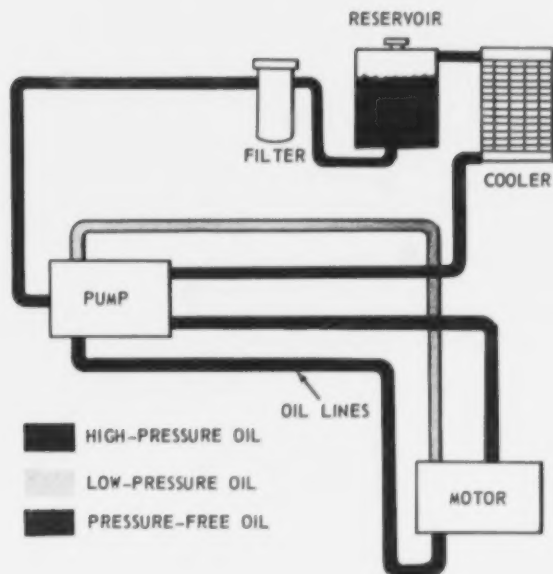


Fig. 15—Complete Hydraulic System for Hydrostatic Drive

simplified, with the hydrostatic unit supplying infinite speed and torque ranges as well as reverse speeds.

Hydrostatic transmissions use fluids at *high pressures* but relatively *low speeds*. Basically, energy is transferred by the fluid itself in a closed circuit between the pump and motor as shown in Fig. 15. While the fluid does move through the lines (shown in red), it is still considered as being at rest or under static pressure. The rise in pressure of the fluid—which will not compress—is what transfers the energy.

OPERATION OF TORQUE CONVERTER

A *torque converter* is also an automatic *fluid drive* (Fig. 16). It transmits engine torque by means of hydraulic force, shifting smoothly through an infinite number of speeds.

Actually a gear train is used with the torque converter to give extra speed ranges. But no gear train could give the infinite variations in speed and torque of a torque converter.

Acting as a *clutch*, the torque converter connects and disconnects power between the engine and the gear train. As a *transmission*, the converter gives many more speed ratios than are practical with a strictly mechanical gear box.

To compare a torque converter with a hydrostatic drive, use this rule of thumb:

Hydrostatic drives are driven by fluids at high pressure but at relatively low velocity, while torque con-

verters are driven by fluids at low pressure but at high velocity.

Here are the formulas:

- *Hydrostatic Drive* = HIGH pressure + LOW velocity
- *Torque Converter* = LOW pressure + HIGH velocity

The basic torque converter system is shown in Fig. 16.

A fluid at high velocity strikes a turbine and forces it to turn, driving the wheel. Thus, *torque is transmitted by a fluid*.

To change this torque, the velocity of the fluid is changed. At low velocity, the fluid will not even move the turbine. At high velocity, the turbine starts turning and the wheel picks up speed.

Inside an oil-filled housing (Fig. 16, left) are two parts: the driving half, or pump, and the driven half, or turbine.

As the pump is turned by the engine, centrifugal force causes oil to be forced radially outward, crossing over and striking the vanes of the turbine. This rotates the turbine in the same direction and so couples the power.

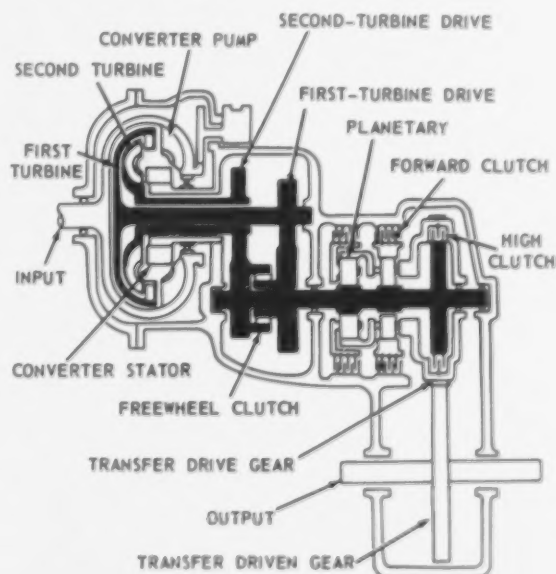
The torque or power from the turbines then flows through the gear train as shown to the power output.

OPERATION OF DIFFERENTIALS

The *differential* does two jobs:

- Transmits power "around the corner" to the drive axles.

Fig. 16—Torque Converter In Complete Power Train



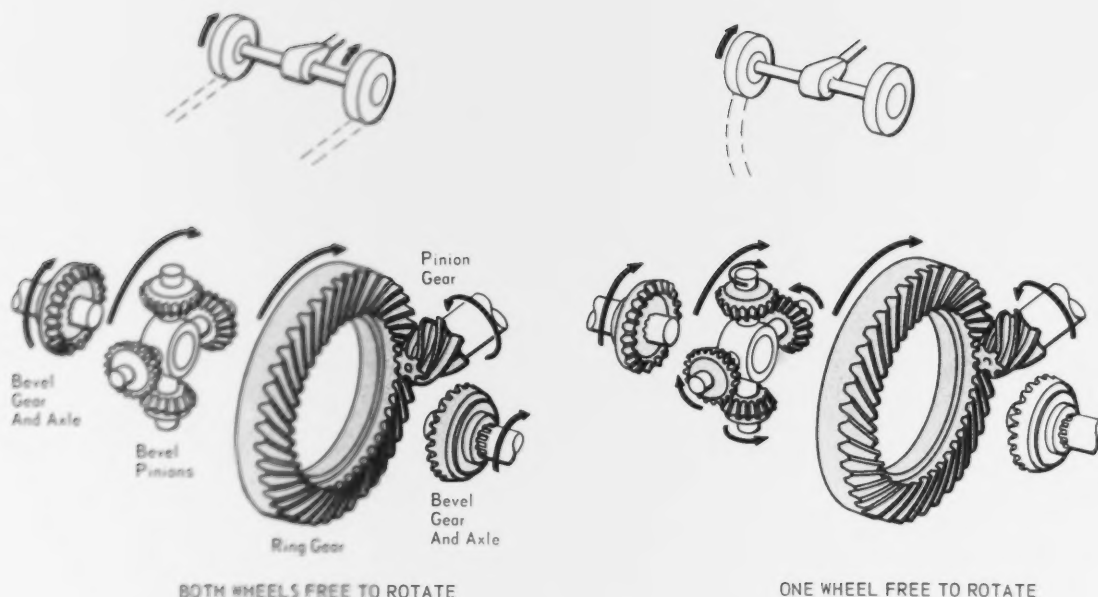


Fig. 17—Differential In Complete Power Train

- Allows each drive wheel to rotate at a different speed and still propel its own load.

The ring gear and bevel gears direct the power to the axles, while the bevel pinions give the differential action (Fig. 17).

When the machine is moving straight ahead, both wheels are free to rotate as shown in Fig. 17, left.

Engine power comes in on the pinion gear and rotates the ring gear. The four bevel pinions and the two bevel gears are carried around by the ring gear and all gears rotate as one unit. Each axle receives the same rotation and so each wheel turns at the same speed.

When the machine turns a sharp corner, only one wheel is free to rotate as shown in Fig. 17, right.

Again engine power comes in on the pinion gear and rotates the ring gear, carrying the bevel pinions around with it. However, the right-hand axle is held stationary and so the bevel pinions are forced to rotate on their own axis and "walk around" the right-hand bevel gear.

Since the bevel pinions are in constant mesh with both bevel gears, the left-hand bevel gear is forced to rotate because it is subjected to the turning force of the ring gear which is transmitted through the bevel pinions.

During one revolution of the ring gear, the left-hand gear makes two revolutions—one with the ring gear and another as the bevel pinions "walk around" the other bevel gear.

As a result, when the drive wheels have unequal resistance applied to them, the wheel with the least resistance turns more revolutions. As one wheel turns faster, the other turns slower by the same amount. However, both wheels still propel their own loads—but at different speeds.

Differential action can be a disadvantage when the wheels slip. For example, when a farm tractor is plowing, one wheel may lose resistance on slick ground and start spinning while the other wheel holds. Then the driving power is limited by the "wasted" power sent to the wheel that slips.

To prevent this loss of power, differential locks are often used.

OPERATION OF DIFFERENTIAL LOCKS

A **differential lock** directs power equally to both wheels by locking out the differential. This prevents the usual loss of traction when one wheel is slipping.

Three types of differential locks are used:

- Mechanical
- Hydraulic
- Automatic (no-spin)

The **mechanical differential lock** (Fig. 18) is the simplest. When the operator moves the control lever, a fork shifts a splined collar on the axle shaft to engage the collar with splines on the differential housing. This forces the axle and housing to rotate as a unit. The bevel gears are thus prevented from turning and so the

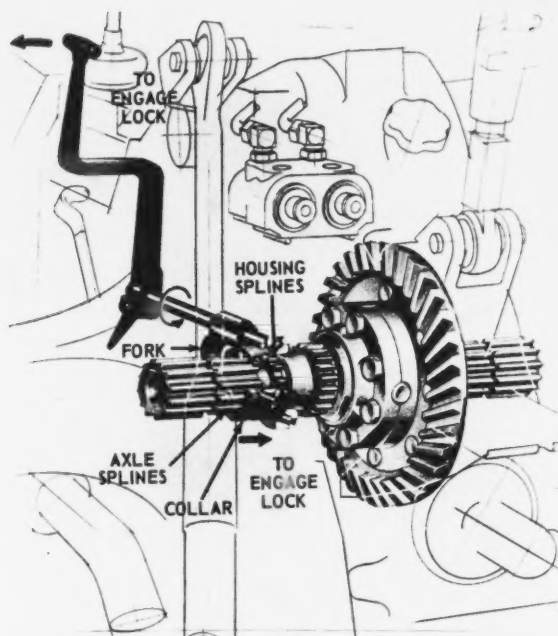


Fig. 18—Mechanical Differential Lock

differential is locked.

When drive wheels again have equal traction, the lock disengages automatically. The lock can be engaged on the go, but must be released before the machine is turned.

When the operator depresses the control pedal, a hydraulic clutch engages the **hydraulic differential lock**. When the pedal is released, oil pressure is cut off and the lock releases as soon as both wheels have equal traction. A safety release connects the control pedal to the tractor's brake pedals to unlock the differential whenever the brake pedals are used. This avoids the danger of making sharp turns with the differential lock still engaged.

The **automatic no-spin lock** (Figs. 19 and 20) is located inside the differential housing and replaces the bevel gears, bevel pinions and their shafts. The no-spin lock is normally engaged and still permits relative motion between the wheels on corners. When engaged, it prevents one wheel from spinning when it loses traction and thereby depriving the other wheel of full power.

However, the no-spin lock does not permit the inside wheel on a turn to slow down — only the outside wheel to speed up. It therefore tends to increase machine turning radius and, in a sharp turn, may prevent the machine from decelerating to a safe turning speed.

OPERATION OF FINAL DRIVES

The *final drive* is the last phase of the power train. It

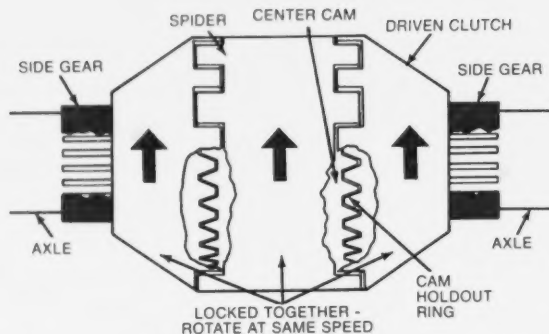


Fig. 19—Automatic No-spin Lock (Driving Straight Ahead)

gives the final reduction in speed and increase in torque to the drive wheels (see Fig. 2).

Used on most large machines, the final drives are mounted near the drive wheels to avoid the stress of long axle shafts.

By reducing speeds, the final drives lower the stress and simplify the transmission, since extra gears and shafts can be eliminated.

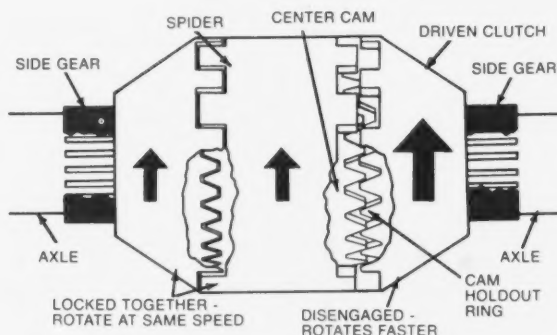
Most final drives must support the weight of the machine as well as withstanding torque and shock loads.

OPERATION OF POWER TAKE-OFFS

The *power take-off (PTO)* is an attachment in the power train of a machine. It drives auxiliary equipment.

PTO's are normally gear-driven from the transmission and send power through a shaft to the PTO outlet where the driven equipment is coupled.

Fig. 20—Automatic No-spin Lock (Left Turn)



Most modern units are adjustable to drive equipment at standard speeds of either 540 or 1000 rpm.

The PTO is operated by a clutch release, which is sometimes part of the main engine clutch.

SERVICING OF POWER TRAINS

The power train requires important maintenance, as we will see now.

SERVICING OF ENGINE CLUTCHES

Because the foot clutch is the most commonly used on most machines today, we will cover its maintenance only. Hand-operated clutches require somewhat different service and are found on few modern machines. Therefore, refer to your operator's manual for maintenance procedures for this type of clutch.

The clutch on most machines requires two services:

1. Lubricating the Clutch Release Bearing
2. Adjusting Clutch Pedal Free Travel

Lubricating The Clutch Release Bearing

On many of the newer machines, the clutch release bearing is a prelubricated, sealed bearing and requires no further lubrication until major service is performed on the clutch.

However, on some machines the bearing requires regular lubrication. Many manufacturers recommend that this be done every 250 hours. Refer to your operator's manual for suggested intervals.

If the bearing is lubricated too much or too often, excessive grease may be thrown onto the clutch facing and cause the clutch to "chatter" when engaged and may eventually damage the clutch facing.

Too little lubrication will cause the bearing to fail prematurely.

If the bearing on your machine requires periodic lubrication, proceed as follows:

1. Locate the grease fitting. It may be on the side or bottom of the clutch housing (Fig. 21).

If an external grease fitting is not found, you may have to remove a cover plate to reach inside to lubricate the bearing.

2. Wipe grease fitting clean before attempting to apply grease.

3. Apply lubricant sparingly. One or two short strokes of the grease gun are usually sufficient. Excess grease might leak out and get on the dry clutch disks, causing them to slip.

4. Wipe off excess grease from fitting.

NOTE: Some machines also have power take-off (PTO) clutches which require bearing lubrication.

Adjusting Clutch Pedal Free Travel

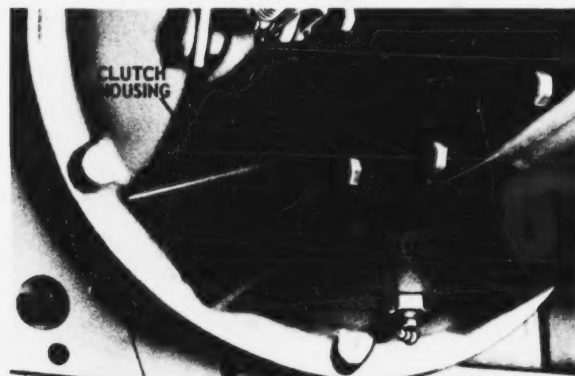
Adjustment of clutch pedal free travel is essentially the same for all non-hydraulic clutches whether they are single or multiple clutch plates, dry or wet type.

Many manufacturers recommend that you check pedal free travel every 250 hours and adjust if necessary. See the recommendations in your operator's manual.

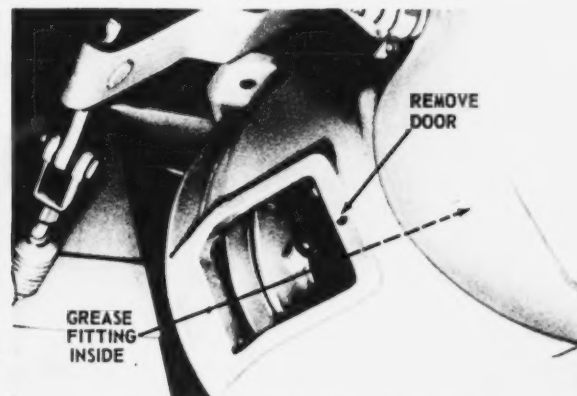
To adjust the clutch pedal free travel, proceed as follows:

1. Refer to your operator's manual for recommended free travel distance. Usually, this may range from $\frac{1}{2}$ to 2 inches (13 to 50 mm) or more depending on the machine and where the distance is measured. Also, determine where the measurement should be taken (for the next step).

Fig. 21—Clutch Release Bearing Grease Fitting



EXTERNAL GREASE FITTING



INTERNAL GREASE FITTING



Fig. 22—Measuring Pedal Free Travel At Pedal



Fig. 23—Adjusting Pedal Free Travel At Pedal Arm

2. Check clutch pedal free travel measurement (Fig. 22). This is the distance the pedal can be depressed before resistance is noticed. The resistance is caused by the clutch release bearing contacting the release levers.

3. If the measurement checks with those specified in your operator's manual, no adjustment is necessary.

4. If the measurement is different than those specified, proceed with the following steps.

5. Locate pedal adjusting mechanism (Fig. 23). Usually the adjustment is made near the pedal or it may be anywhere along the linkage leading to the clutch release mechanism.

6. Adjust the linkage, as necessary, until the clutch pedal has the proper amount of free travel.

SERVICING TRANSMISSION, DIFFERENTIAL, AND FINAL DRIVES

Your machine may have a transmission that resembles one of those shown in Fig. 24 or it may have separate differential and final drives.

In Fig. 24, the transmission reservoirs are shown in blue, while the filler and drain plugs are shown in red. Here is an explanation:

(A) All gear drive units housed within one compartment. Hydraulic system separate.

(B) A one-compartment arrangement which also contains hydraulic pump and uses gear oil for hydraulic system.

(C) A two-compartment arrangement with one compartment supplying lubrication to the belt pulley and wet clutch and providing fluid for the hydraulic system.

(D) A four-compartment assembly with a separate hydraulic system but with only a partial division between the transmission and differential sections.

(E) A three-compartment assembly with one compartment supplying the torque converter and wet clutch with lubricant. Note the hydraulic system is supplied from the power take-off compartment.

(F) High-clearance tractors often use a spur-gear drive at the ends of the main axle. Each of these has its own lubricating compartment.

Regardless of its design, the maintenance of the transmission is similar to the following service procedures.

Checking Oil Levels

Operator's manual may recommend checking the transmission oil levels from every 50 to every 250 hours.

OIL LEVEL DIPSTICK

If the machine has a dipstick (Fig. 25) for checking the oil level, remove it and wipe off the excess oil. Reinsert

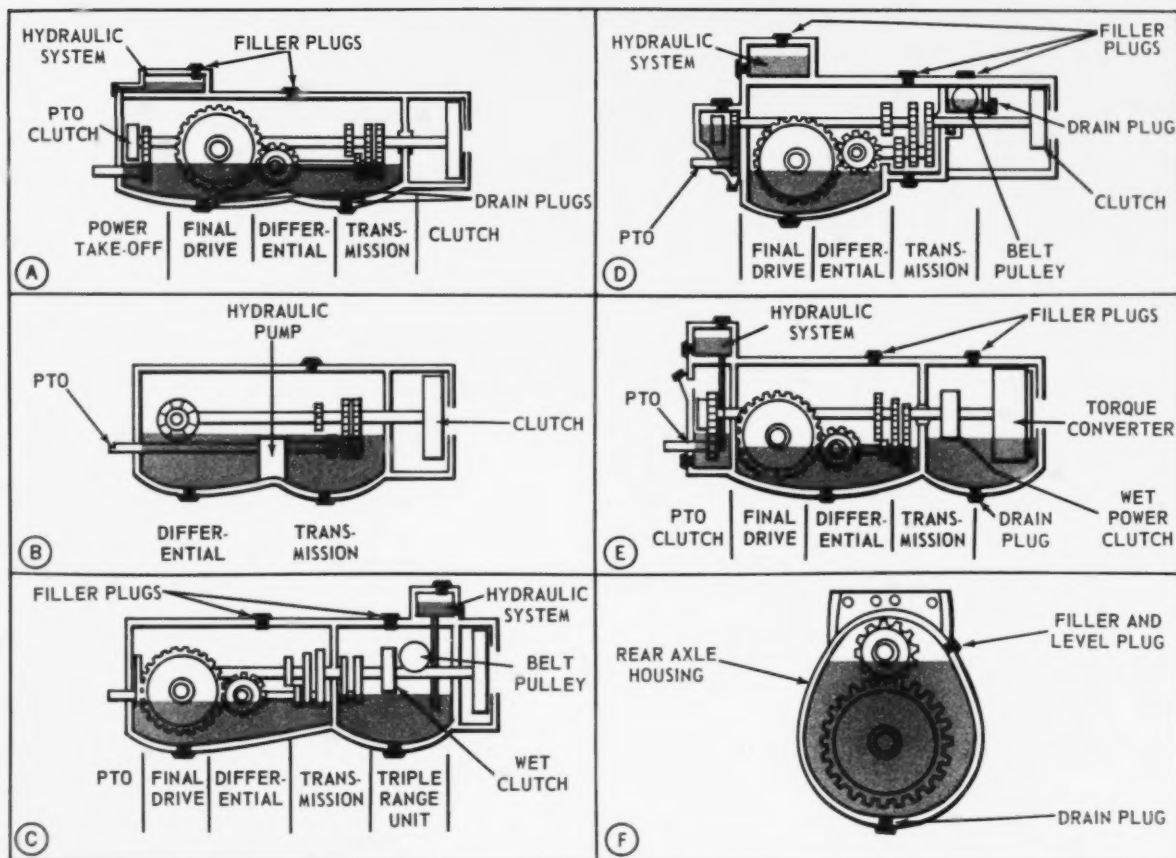


Fig. 24—Basic Power Train Designs Showing Fluid Reservoirs

Reinsert the dipstick completely and pull it out again to check the oil level.

If the level is below the full mark (or "safe" mark), fill to the proper level with the recommended oil of the proper viscosity. Make the level check with the engine running, or according to other recommendations.

OIL LEVEL PLUG

If your machine doesn't have a dipstick, remove the oil level plug (Fig. 26) from the transmission case.

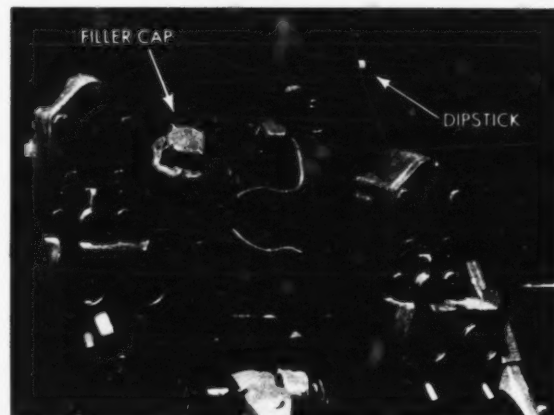
On machines with separate final drives, remove the oil level plug (Fig. 27) from them also. Insert a finger to determine if oil is up to proper level.

If necessary, refill with the recommended oil of the proper viscosity.

Draining And Refilling

The usual draining and refilling period is at least once each year. Others recommend every 1000 hours or less. See your operator's manual.

Fig. 25—Transmission Oil Level Dipstick



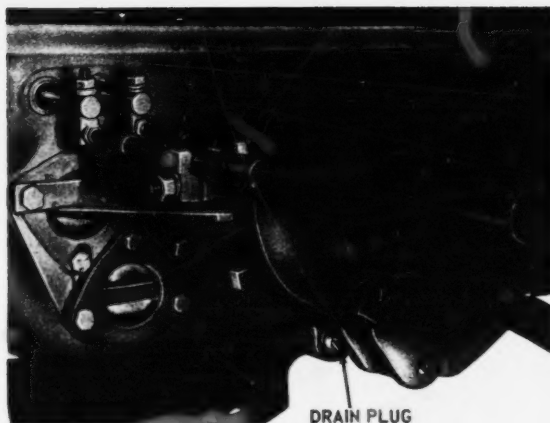


Fig. 26—Transmission Oil Level Plug

Tools and Materials Needed

- Wrenches for drain plug(s) and filter cap (inch or metric, as required)
- Clean, lint-free cloths
- Cleaning solvent (not gasoline)
- New oil of type and grade recommended by manufacturer
- New filter
- Container to catch waste oil

Fig. 27—Final Drive Oil Level Plug

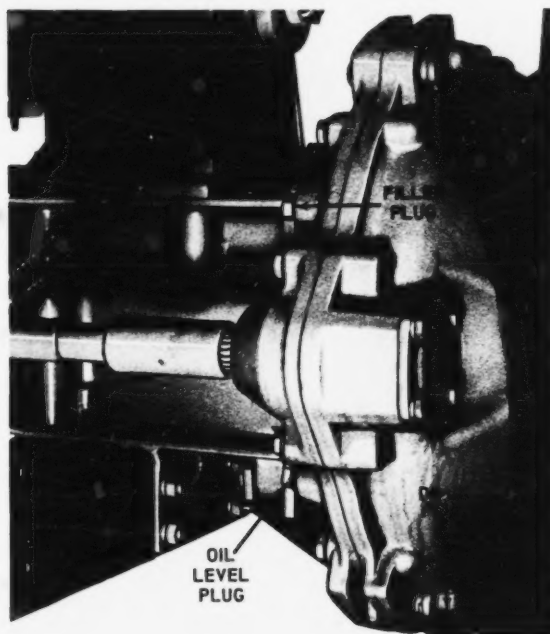


Fig. 28—Using A Metal Shield To Divert Oil Away From Tire

To drain and refill the transmission, proceed as follows:

1. Drive the machine until you are certain the transmission fluid is well agitated and heated. This helps ensure that most of the sludge and dirt will drain out when the fluid is removed.
2. Park the machine on a level surface. This will ensure better draining position than if the machine is on a slight incline.
3. Remove drain plugs (Figs. 26 and 27) and catch the old fluid in a container.

If the transmission has the differential and final drives in the same housing, you will probably need to remove two plugs. If the final drives are separate, you may have to remove three plugs or more.

When the final drive is near the tire, use a metal shield to divert the oil away from the tire and into a container as shown in Fig. 28.

After all the fluid has drained out, clean the drain plugs; replace and tighten them. Be particularly careful to clean magnetic drain plugs of any metal particles.

4. Replace transmission oil filter if there is one (Fig. 29).
5. Clean dirt and grease from filler plug and surrounding area. Remove plugs.
6. Refill with the proper amount and type of transmission fluid or gear oil as specified in your operator's manual.

Do not overfill; this will cause excessive agitation and foaming.

IMPORTANT: If the machine has one common reservoir for both the transmission and hydraulic systems, use special care in cleaning and in replacing with transmission-hydraulic fluid of the correct type. Pre-

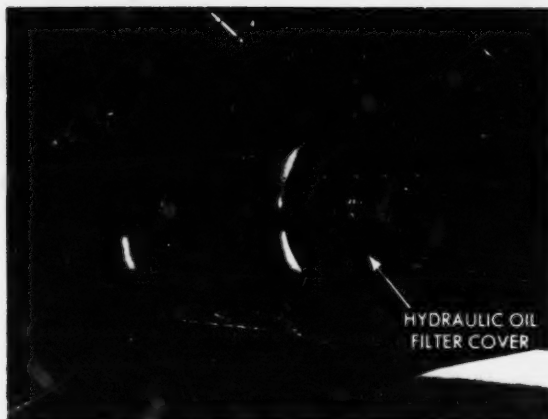


Fig. 29—Transmission-Hydraulic System Filter Covers

cision hydraulic parts can be seriously damaged by dirt or the wrong fluid.

7. Replace and tighten plugs.

8. If equipped, clean filler cap and breather (Fig. 19) in solvent (not gasoline). Shake out excess liquid. Add a small quantity of oil to filter and shake out excess. Replace cap.

ADJUSTING TRANSMISSIONS

Transmission adjustments are usually performed at the time of major repairs. Gear trains are then adjusted for preload, backlash, or endplay (see Chapter 9 under "Gear Drives"). Other adjustments, as of shifting linkages, should be made per instructions in the machine operator's manual.

Adjustment of hydraulic power transmission units requires special test equipment and should be done only by a trained serviceman. The basic use of a hydraulic tester for diagnosis is given at the end of Chapter 8, "Hydraulic Systems".

PRECAUTIONS FOR TOWING MACHINES

On some machines the engine must be turning the transmission gears to obtain proper lubrication. Towing such a machine would result in poor lubrication and high shaft speed. The failure of many transmis-

sions can be traced to towing.

If the transmission gears are operated at excessively high speeds, the gear lubricants will become overheated. Overheating a lubricant causes it to oxidize and thicken. Continuous overheating would result in transmission failure.

When towing a machine there is danger, too, that a brake may grab. The machine may bounce and be hard to steer. If the tires are filled with liquid, the high speed can also damage a tire.

If it becomes necessary to tow a farm machine, do so slowly. It is much better to haul the machine or drive it under its own power. Some machines have a lever that permits the transmission gears to be disengaged so they can be towed. Other machines must have the engine running to maintain power operation of steering and brakes for safety. Refer to the operator's manual for precautions.

CHAPTER QUIZ

1. True or false? "Gear oil may have the same viscosity as engine oil."
2. What three types of oils or fluids are used in transmissions?
 - a. _____
 - b. _____
 - c. _____
3. If you must store lubricants in unprotected barrels, how should they be positioned to avoid contamination?
4. Why does clutch pedal free travel change periodically and require readjustment?
5. What may happen if you over-lubricate the clutch release bearing?
6. What should you do with the machine before draining old fluid from the power train?

8

Hydraulic Systems

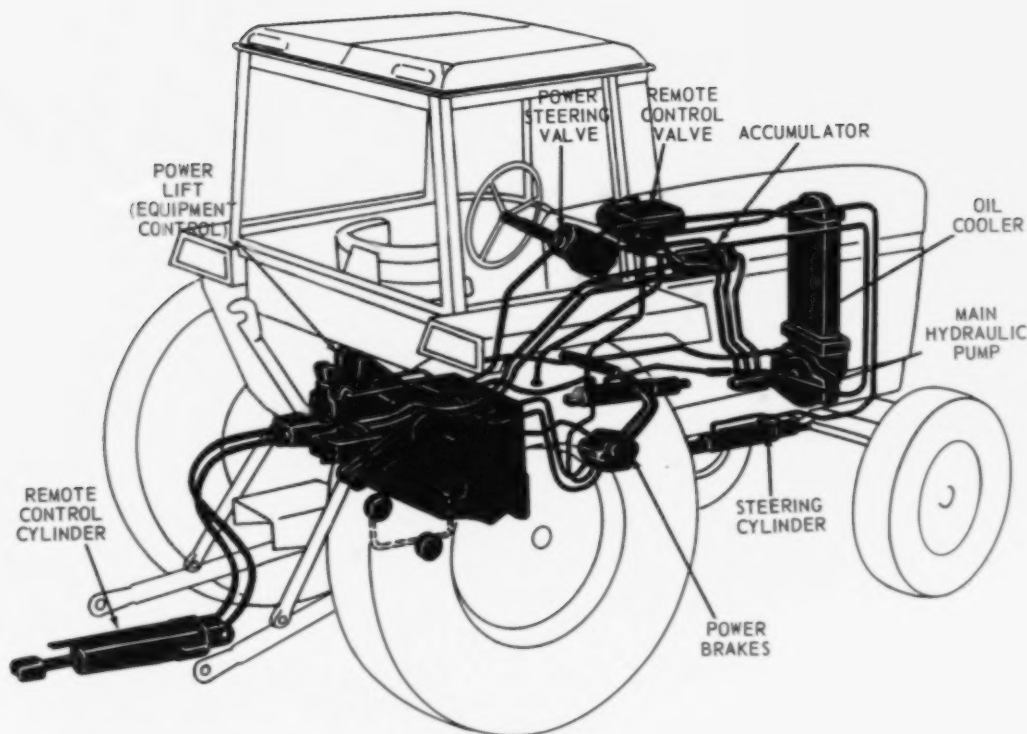


Fig. 1—Modern Farm Tractor With Full Hydraulics

INTRODUCTION

Hydraulic systems (Fig. 1) provide the "muscles" for doing work. Some machines, like the tractor in Fig. 1, have a hydraulic system that performs several functions: steer, brake, control implements, and operate remote functions. Other machines may have only one or two hydraulic functions. All the functions may share a common oil supply or they may have their own reservoirs.

The most common hydraulic functions are:

- **Steering**
- **Brakes**
- **Transmissions (chapter 7)**
- **Implement Control**
- **Remote Cylinders**
- **Hydraulic Motors**

We'll discuss some of these systems later.

IMPORTANCE OF SERVICE

A well-maintained hydraulic system seldom gives the operator any trouble. Regular checks assure that the oil level is sufficient. Changing the oil and filters regularly helps prevent problems.

The oil in the hydraulic system is extremely sensitive to contamination. Dust, rust, moisture, and metal particles will damage the hydraulic system.

Hydraulic fluid lubricates and cools the entire hydraulic system. Any contaminant which builds up in the fluid can ruin the whole system.

Routine checks and repair of oil leaks will prevent excessive loss of fluid and overheating. Air leaks will cause the oil to oxidize rapidly, forming harmful gum and sludge. Check for air leaks and repair them promptly.

SELECTING HYDRAULIC FLUIDS

The fluid in a hydraulic system serves as the power transmitting medium. And as stated above, the fluid is also the

system's lubricant and coolant. Selection of the proper oil is essential for satisfactory performance and life. Oil must be selected with care and from a reputable supplier. Be sure to use the manufacturer's recommended oil.

These are some common hydraulic system oils:

1. **Crankcase Oil** meeting API service classification CD or SF. The most severe classification is the key to proper selection of crankcase oils for mobile hydraulic systems.

2. **Antiwear Hydraulic Oil**—There is no common designation for oil of this type. However, they are produced by all major oil suppliers and provide the antiwear qualities of CD or SF crankcase oils.

3. **Certain Other Types Of Petroleum Oils** are suitable for mobile hydraulic service if they meet the following provisions:

a. Contain the type and content of antiwear compounding found in CD or SF crankcase oils or have

passed pump tests similar to those used in developing the antiwear-type hydraulic oils.

b. Meet the viscosity recommendations for expected temperatures.

c. Have the chemical stability for mobile hydraulic system service.

The following types of oil are suitable if they meet the above three provisions:

API CD Diesel Engine Oil

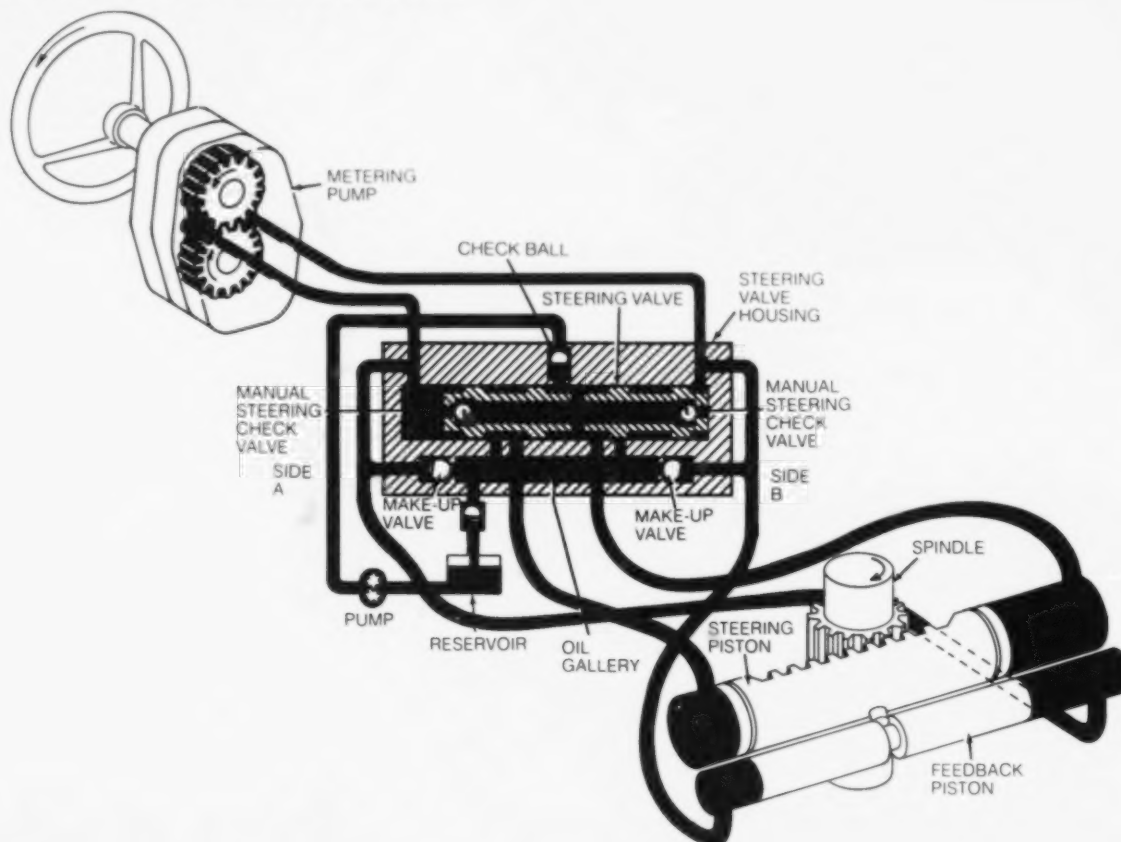
MIL-L-2104C

Type F and DEXRON II

Hydraulic Transmission Fluid Type C-3

When selecting hydraulic fluids, check the recommendations in the operator's manual. The manufacturer has picked a fluid which meets all the needs of the system, which may vary from simple cylinders to precision hydraulic pumps.

Fig. 2—Metering-Pump Power Steering During A Right Turn



OPERATION OF HYDRAULIC SYSTEMS

A brief introduction to how hydraulic systems work will help you to understand why proper maintenance is so important.

The operation of three common hydraulic operations will be discussed:

1. *Hydraulic Steering*
2. *Power Brakes*
3. *Implement Control*

HYDRAULIC STEERING

Two types of hydraulic steering are used:

- **Hydraulic Assist Steering**
- **Full Power Steering**

HYDRAULIC ASSIST STEERING (not shown) is similar to mechanical steering, except for a hydraulic valve controlled by the steering wheel and hydraulic pistons which assist the steering mechanism in turning the wheels.

Since full power steering is the most popular today, we will discuss it more fully.

Fig. 2 shows a power steering system with a metering pump operating during a right turn.

NOTE: Indications of directions refer to those as seen from the operator's seat. Side A and B will help identify direction of movement in the steering valve housing.

When the operator turns the wheel to the right the gears in the metering pump direct oil in the steering system to the steering valve housing and to the left end of the feedback piston. This oil (under some pressure) moves the steering valve toward side B.

The movement of the steering valve opens the pressure oil circuit to the left end of the steering piston. Oil from the right end of the piston flows back to the steering valve oil gallery and to the reservoir.

Oil from the right end of the feedback piston cylinder is forced out, by piston movement, and returns through the steering valve housing to the metering pump.

This movement of the steering and feedback pistons from left to right causes the spindle to rotate clockwise and turn the front wheels to the right.

When the operator stops turning the steering wheel, the gears in the metering pump stop directing oil to the steering valve. Circuit pressure, from the right end of the feedback piston to the steering valve, (caused by movement of the feedback piston) acts against the side B of the steering valve. The valve moves toward side A, closing the pressure oil passage from the main hydraulic pump, and stops the turning movement. The valve becomes centered and traps oil in passages to both sides of the steering piston. The trapped oil holds the wheels in the right turn until the operator again turns the steering wheel.

If oil is lost from the control circuit, pressure in the control circuit drops. The reduced pressure causes the make-up valve to unseat and allow return oil from the steering piston to make up oil in the control circuit.

On articulated tractors, the steering and feedback pistons are replaced by hydraulic cylinders which control steering.

To protect against failure of power steering, a check ball and manual steering check valves are used in this power steering systems. If the oil supply fails and no incoming oil pushes the check valve open, it closes and traps all oil within the steering circuit.

This allows the operator to steer manually by using the trapped oil as a force to actuate the steering. Pressure is created as the operator turns the steering wheel.

For manual steering, see Chapter 9.

POWER BRAKES

On most machines, brakes are located on each drive wheel. For turning, the operator presses down the pedal for the left or right wheel. For stopping, he presses down on both pedals at once.

On four-wheel drive machines, a single brake mechanism at the transmission usually controls the whole unit.

Because manual brakes and hydraulic brakes are not powered by the hydraulic system, we will cover them in the next chapter. However, in some systems, oil is supplied to the brake reservoir by the tractor hydraulic system and bleeding these brakes will be covered later in this chapter.

Let's discuss the operation of *power brakes* in more detail.

"Power" brakes mean that hydraulic force completely controls the braking of the machine, once the operator presses down the brake pedal to actuate the valving.

Full power brakes on a modern wheel tractor with a closed-center hydraulic system are shown in Fig. 3. Operation is shown during a left turn.

For a sharp left turn, the operator presses down on the left brake pedal. This causes a rod linkage to push down on the brake valve and open it. Inlet oil under pressure now rushes in through the open valve, forces the outlet check valve open, and flows on to the final drive at the left rear axle (see inset). Here the oil forces the brake pistons and pressure plates to press the revolving brake disk against a fixed plate and so brakes the left axle and wheel.

When the brake pedal is released, the brake valve is closed again by its spring, and inlet oil is shut off. This relieves pressure on the brake disk at the axle, and

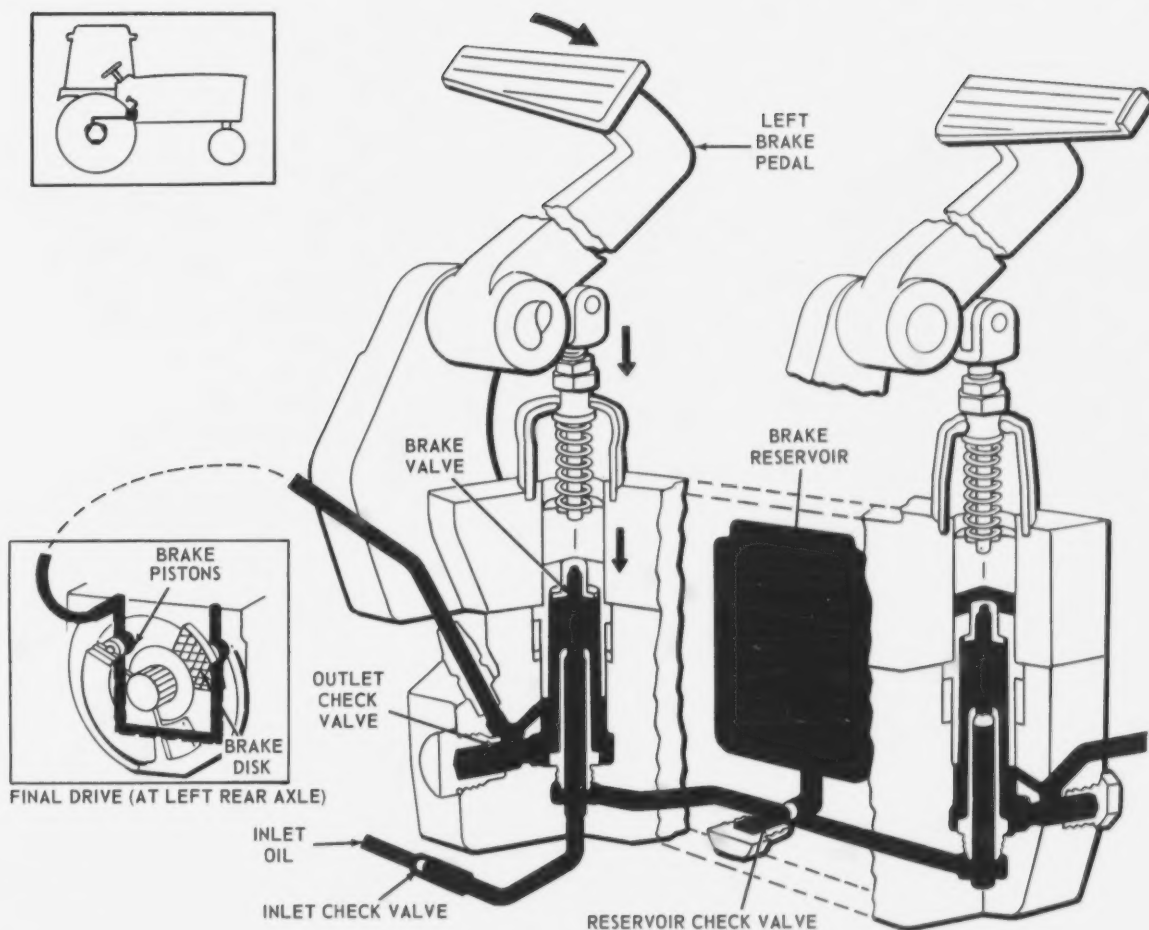


Fig. 3—Power Brakes During A Left Turn

braking stops as some oil flows back to the brake valve area. This oil dumps into the brake reservoir after going past the valve and through the valve plunger. When both brake pedals are pressed down at once, oil is sent by both brake valves to both final drives. To assure equal braking, equalizing valves (not shown) are opened, connecting the two brake valves.

To protect the operator in case of failure of power brakes, oil trapped in the brake valve reservoir by the check valves allows temporary operation of the brakes. On large machines, a hydraulic accumulator stores "charges" of oil for emergency braking.

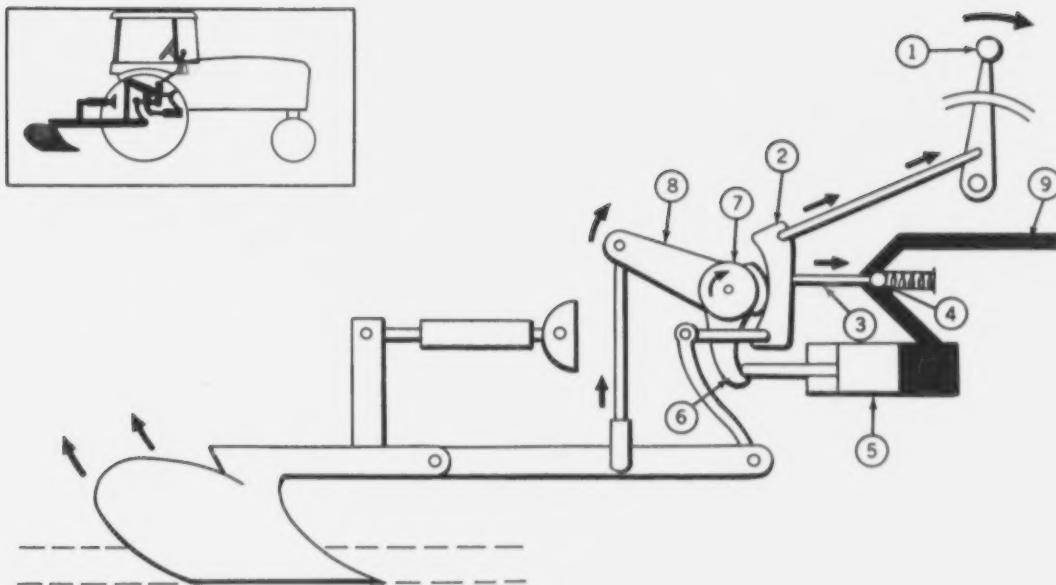


Fig. 4—Raising The Plow Using The Control Lever

- | | |
|-----------------|-----------------|
| 1—Control Lever | 6—Shaft Arm |
| 2—Cam Follower | 7—Rockshaft |
| 3—Operating Rod | 8—Lift Arm |
| 4—Valve Ball | 9—Oil From Pump |
| 5—Piston | |

IMPLEMENT CONTROL

Two types of implement control systems are used on tractors:

- **Power Lift (Rockshaft)**
- **Remote Control**

The power lift is used to control mounted implements, while remote control cylinders are usually placed on a pull-type implement to control a function such as raising the plow bottoms.

Power Lift

The power lift usually is controlled either manually using a control lever or automatically by load sensing.

RAISING PLOW USING CONTROL LEVER

In Fig. 4, the plow hits hard ground and the operator wants to raise it slightly. So he moves the control lever (1) to the front. This pivots the cam follower (2) forward and presses it against rod (3) which opens valve (4). Pressure oil is now admitted to the cylinder, forcing piston (5) to the rear. The piston pushes against the shaft arm (6), rotating rockshaft (7) and lift arm (8) upward. The lift arm is attached to the plow and so the

plow is raised slightly to help it pass through the hard ground.

The plow stops rising when the valve (4) is closed again, trapping oil in the cylinder. This happens when the cam follower (2) working on the sloping cam of the rockshaft (7), is returned to the rear and releases the rod (3). The valve is then closed by its spring.

AUTOMATIC LOAD SENSING RAISES THE PLOW

In Fig. 5, the plow hits hard ground (1) and load control shaft (3) is pulled rearward by draft links (2). As a result, load control arm (12) is pivoted against cam follower (4). The cam follower pushes on rod (5) which opens valve (6) and admits pressure oil to cylinder (7). The cylinder piston pushes against the arm (8), rotating rockshaft (9) and lift arm (10) upward. The lift arm is attached to the plow and so raises the plow slightly to help it pass through the hard ground.

With automatic load sensing, the plow will lower itself again when the hard ground is passed. This happens as the tension on the load control shaft (12) is partly released. It flexes forward and pulls back on the linkage to actuate other valves (not shown) which release some oil from the cylinder. This lets the lift arms (10) "settle," lowering the plow again.

The regular depth of the plow can be set at the control lever. The plow will stay at this depth unless a signal is given by the load sensing device.

We have just described full load sensing or *load control*.

Two other options are commonly available: if he wishes, the operator can lock out signals from the

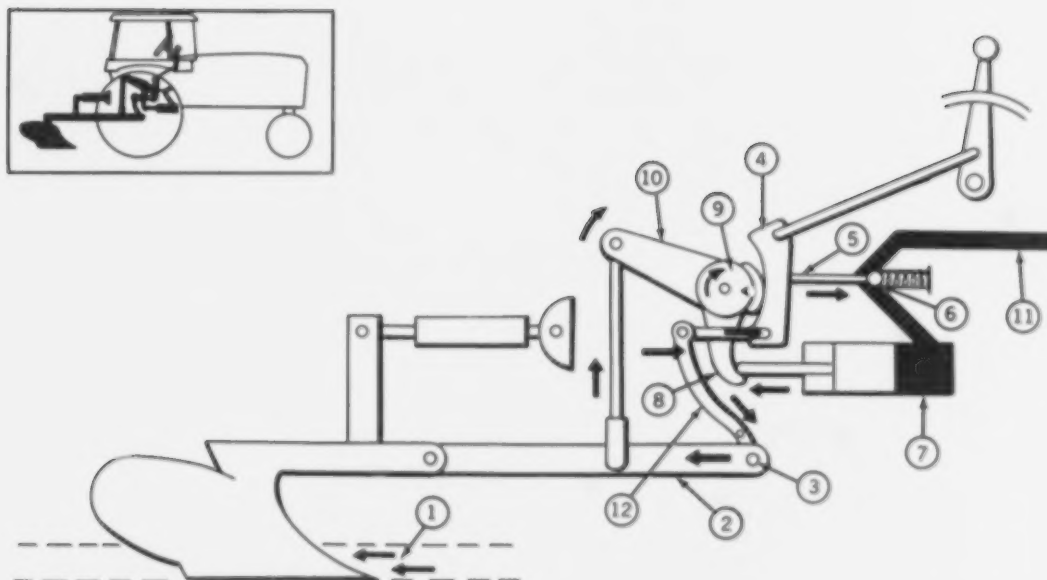


Fig. 5—Automatic Load Sensing Raises The Plow

- | | |
|----------------------|---------------------|
| 1—Plow Furrow | 7—Cylinder |
| 2—Draft Link | 8—Shaft Arm |
| 3—Load Sensing Shaft | 9—Rockshaft |
| 4—Cam Follower | 10—Lift Arm |
| 5—Operating Rod | 11—Oil From Pump |
| 6—Valve Ball | 12—Load Control Arm |

load sensing linkage by blocking the cam follower (4) at its lower end using a lever (not shown). This is called *depth control*, since the plow now stays at the depth set by the control lever. The other choice allows the operator to partially block the cam follower using the same lever. This is called *load and depth control*, since the load signals are now modified by the depth setting.

Some power lifts are designed for dual operations. Two hydraulic cylinders are normally used: one cylinder and valving controls the rear-mounted equipment, and the second operates a front-mounted tool or an attachment. However, the cylinders can be operated in parallel by opening valves which join them to the same pressure oil supply. Two control levers are also used, one for each function. But usually only one function (the rear one) has an automatic load sensing device.

HYDRAULIC LOAD SENSING RAISES THE PLOW

The hydraulic load sensing system (Fig. 6) consists of a load control valve (1) and a sensing cylinder (2). The load control selector (3) is in a position at the top of the cam follower (4) to allow maximum load sensing. The rod end of the sensing cylinder piston (5) is attached to one draft arm (6). The two draft arms are connected by a shaft. The draft links (7) are attached to the draft arms.

As the plow hits hard ground (8), the soil resistance increases the draft load on the draft arms. The draft force is transmitted to the sensing cylinder (2) by the draft arms and pulls the sensing cylinder piston and valve (9) rearward. More oil then flows into the sensing cylinder through a variable orifice (10), causing sensing pressure on the front of the load control valve (1) to increase. The increase in sensing pressure results in rearward movement of the load control valve (1), cam follower (4), and valve operating link (12) which causes the valve operating cam (13) to rotate clockwise. Note that an orifice (11) allows some oil to escape from the front of the load control valve. This results in a variable pressure on the valve depending on the amount of oil that enters through the variable orifice (10).

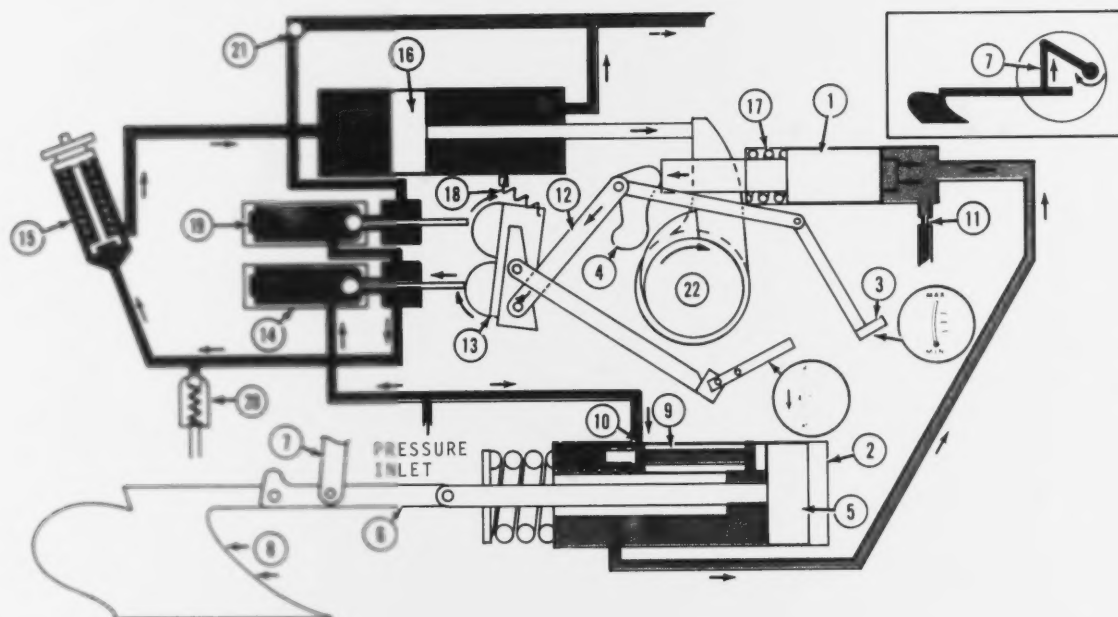


Fig. 6—Hydraulic Load-Sensing Rockshaft

The clockwise rotation of the valve operating cam causes the pressure valve (14) to open and direct pressure oil through the throttle valve (15) to the back-side of the rockshaft piston (16). The throttle valve controls the speed of oil flow to and from the rockshaft piston. The piston moves forward and causes the rockshaft (22) to rotate, lifting the draft links (7) and raising the plow. The check ball (21) prevents return oil from the front of the rockshaft piston from entering the return valve housing (19).

When the plow passes the hard ground, the draft force on the sensing cylinder decreases. The sensing cylinder piston (5) and valve (9) move forward permitting less oil to flow through the variable orifice, decreasing sensing pressure at the front of the load control valve. The spring in the load control valve housing (17) pushes the valve forward. The spring (18) causes the valve operating cam to rotate counterclockwise and forces the cam follower (4) forward, along with the load control valve. The pressure valve (14) closes and, if necessary, the return valve (19) opens to lower the plow.

When the pressure and relief valves are closed, oil trapped at the rear of the rockshaft may expand if the oil temperature rises. The thermal relief valve (20) senses thermal expansion of hydraulic oil in the system and opens if the expansion is too great.

REMOTE CONTROL OF EQUIPMENT

Tractors may operate equipment that is not mounted, but is pulled or pushed. To control this equipment with

hydraulics, a remote actuator such as a cylinder or a motor is needed — separate from the tractor connected by flexible hoses.

Let's take the case of a plow again — this time one that is pulled behind the tractor (Fig. 7). The plow is pulling too hard and the operator wants to raise it. This is what happens:

The operator moves the hydraulic control lever to the front as shown. This actuates the control valve which sends pressure oil to the front of the remote cylinder. As this oil pushes the piston to the rear, the cylinder rod extends. Oil from the other side of the piston is forced out and returns through the valve to reservoir. As the cylinder rod extends, it pivots a linkage to the plow axle, rotating the bent axle to the rear and so raises the plow.

Remote cylinders have hundreds of uses on modern machines.

Another use of remote hydraulics is the *hydraulic motor*. For example, a small hydraulic motor can be mounted on a portable grain elevator as shown in Fig. 8. The motor converts fluid power into rotary motion which drives the elevating mechanism. Pressure oil supply usually comes from a machine hydraulic outlet.

We have covered only the most common uses of hydraulics of modern machines. However, our primary aim is to describe maintenance.

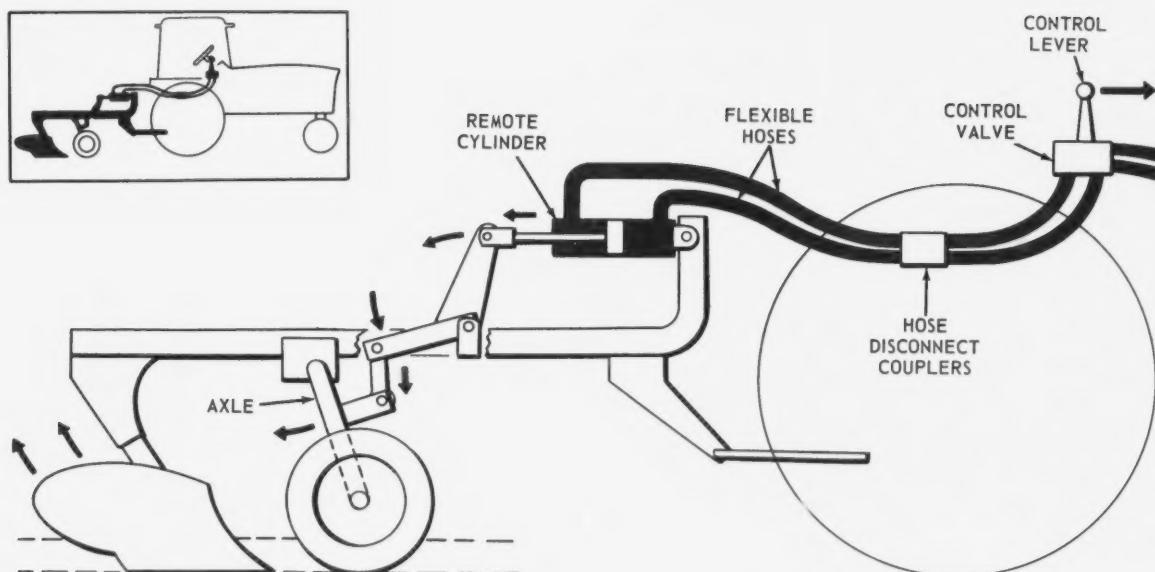


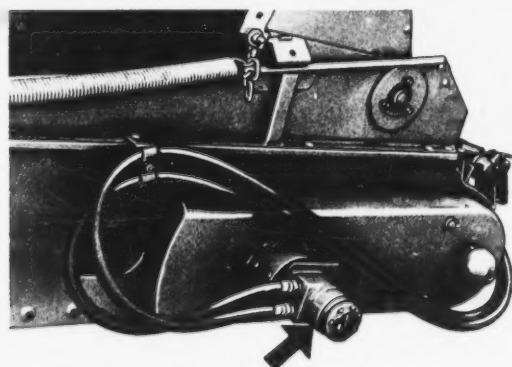
Fig. 7—Raising A Pull-Type Plow Using Remote Cylinder Hydraulics

SERVICING THE HYDRAULIC SYSTEM

There are four basic maintenance problems with hydraulic systems:

- **Not enough oil in the reservoir**
- **Clogged or dirty oil filters**
- **Leaking connections**
- **Incorrect oil in the system**

Fig. 8—Small Hydraulic Motor Used To Drive Portable Grain Elevator



All these problems can be solved or prevented by knowing the system and maintaining it properly.

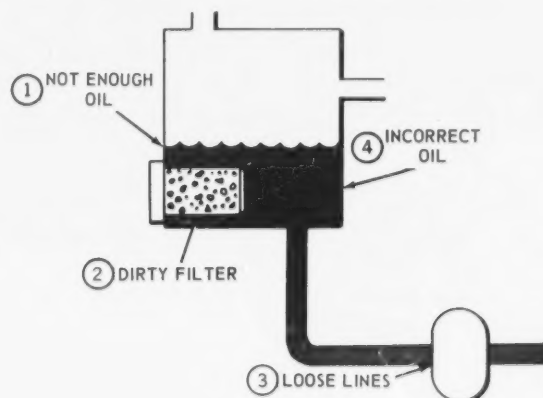
Let's discuss some of the practices which will keep the hydraulic system in top-notch condition.

CHECKING OIL LEVEL

To check the oil level, most hydraulic systems have either a sight glass in the reservoir or a dipstick (Fig. 10). Check the oil level at least every 250 hours. Some manufacturers recommend daily checks.

If the oil level isn't up to the sight glass or the "Full" or "Safe" mark on the dipstick, fill the reservoir with

Fig. 9—Basic Maintenance Problems With Hydraulic Systems



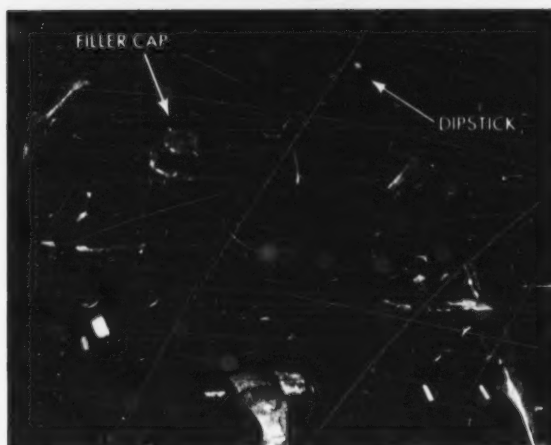
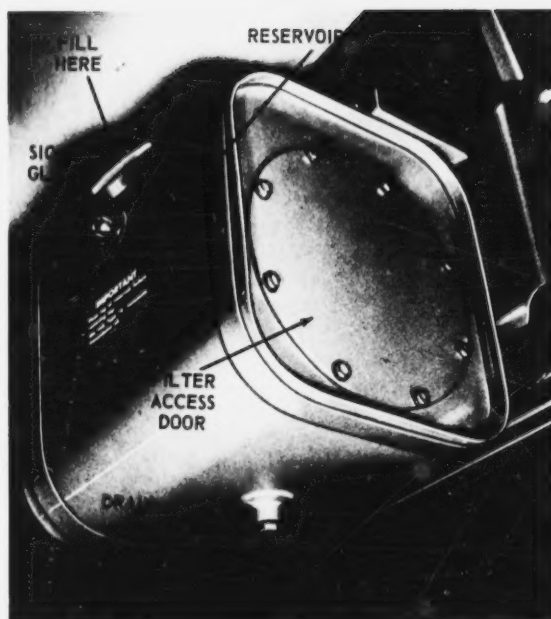


Fig. 10—Two Methods Of Checking Hydraulic Oil Level

the recommended hydraulic fluid. See "Filling the System" later in this chapter.

At this time, also check for other malfunctions in the system. Look for:

1. **Oil Bubbles or Foaming Oil.** This may mean an air leak somewhere in the system.
2. **Changes in Oil Level.** If there is a noticeable change in the oil level from day to day, look for leaks or cracks in the external parts of the system.
3. **Milky Oil.** This indicates water in the system or in the oil used. Be sure that oil is stored properly.

If the reservoir has a breather cap, clean it in solvent.

CHECKING OIL COOLER

Check the oil cooler (Fig. 11) every 250 hours for accumulation of debris. Anything that blocks the flow of air through the cooler could cause overheating of the hydraulic fluid.

CHECKING FOR LEAKS

Excessive oil leakage can cause major damage to a hydraulic system if it goes unrepaired. Check all the hydraulic lines and connections for leaks every 50 hours or even daily if your operator's manual recommends it.

Some hydraulic systems are complex (Fig. 12) and have many lines and connections. With several connections in a hydraulic system, the chances are great that leaks will develop.

Look for:

1. **Pressure Oil Leaks.** Oil leaks in the pressure side of the system can be located by examining the outside of lines and fittings.
2. **Air Leaks.** If the suction side of the system is drawing in air, the oil in the reservoir will bubble and foam.
3. **Pinched or Dented Lines.** This can cause oil foaming, overheating, and loss of hydraulic power. Replace damaged hoses or tubes at once. Wash lines inside and out with clean solvent before installing them.

Fig. 11—Location Of A Typical Hydraulic Oil Cooler



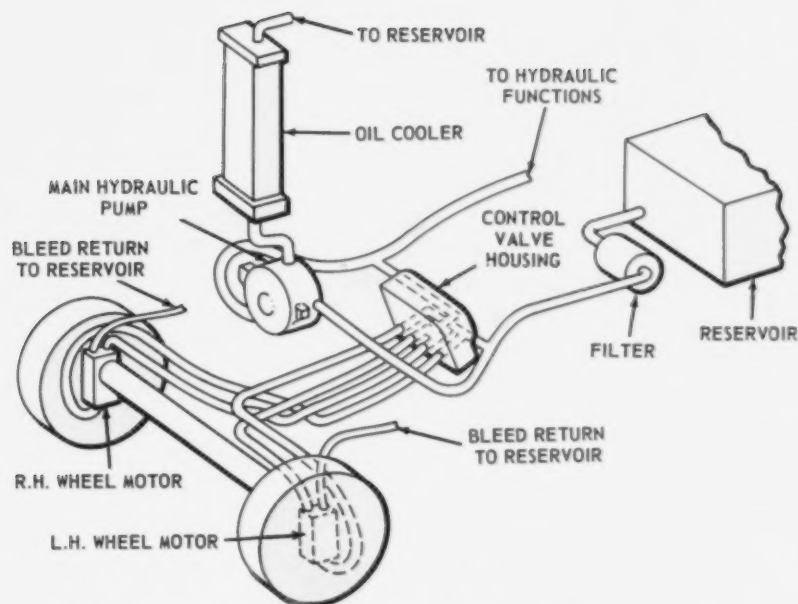


Fig. 12—Hydraulic Systems Have Many Lines And Connections

CAUTION: Do not expose bare skin to pin-hole leaks. Hydraulic fluid under pressure will pierce the skin, causing severe injury. Use eye protection and protective clothing when checking for pin-hole leaks.

Fig. 13—Tightening Hydraulic Fittings



Inspect the machine completely. If any fittings are found to be leaking, tighten them. Use two wrenches to avoid twisting the lines (Fig. 13). Tighten the fittings *only until snug and the leak stops. Do not overtighten.*

When connecting hoses or tightening them, avoid twisting the hose. See Fig. 13 for how to route hoses properly.

Hose Failures

While you are checking for leaks, examine hoses closely. If a hose fails, you may lose all hydraulic fluid in a few moments. This can be dangerous to you and cause damage to the machine.

Look for: cracking, splitting, pin-hole leaks, improper hose length, rubbing, heat, twisting, wrong hose selection, wrong fitting, or improper routing.

Replace any hose showing signs of damage with a new hose designed for exact replacement. *Don't economize!* Selecting a cheaper hose may result in premature failure of the hose.

Component Leaks

If a component of the hydraulic system is leaking, a defective seal may be the problem. Take the machine to a service shop for repair. Do not attempt to repair hydraulic components yourself. Special tools and knowledge are required to repair hydraulic systems.

Refer to "General Maintenance" later in this chapter for suggestions on preventing leaks and testing for internal leaks.

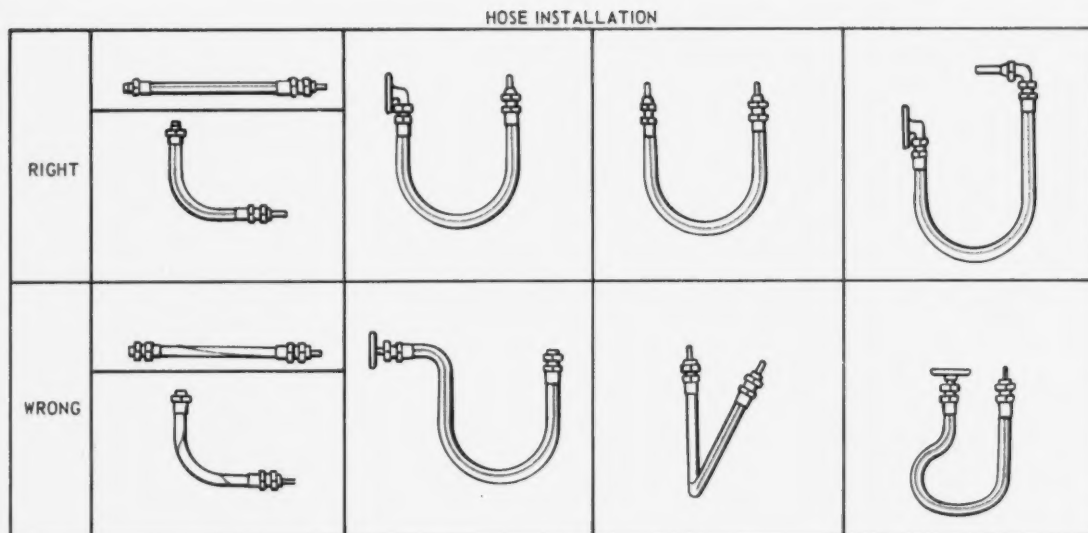
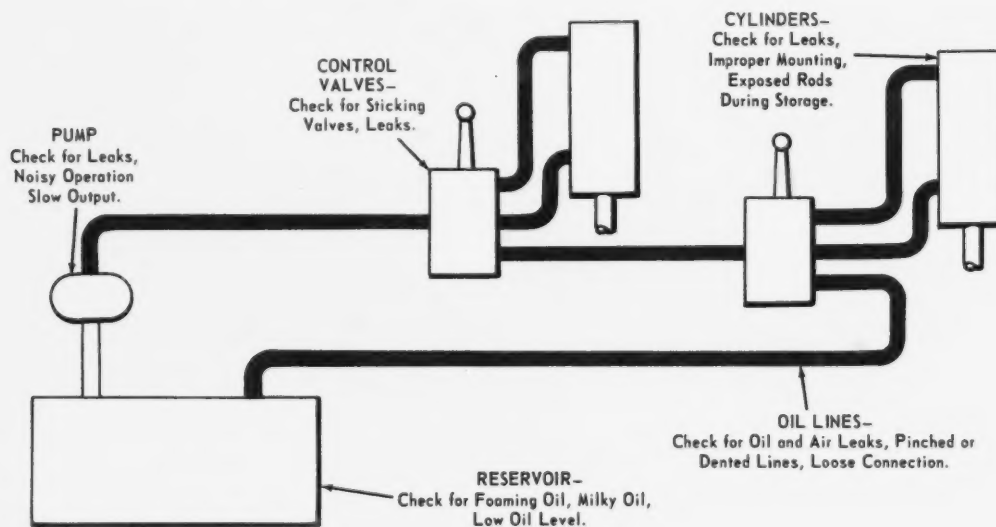


Fig. 14—How To Route Hydraulic Oil Hoses

Fig. 15—Where to Check For Hydraulic Leaks



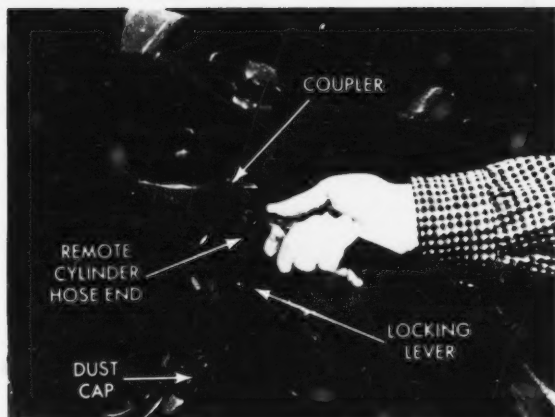


Fig. 16—Connecting Remote Cylinder To Coupler On Machine

MAINTAINING REMOTE CYLINDERS

Remote cylinders require proper care for long service life. This includes correct connection, cleanliness and bleeding air when necessary.

Connecting Of Remote Cylinders

First install the remote cylinder on the implement as instructed in the operator's manual.

Plug the cylinder hoses into the machine couplers (Fig. 15). Some couplers have a rotating lever to lock the hose end into the coupler port.

When removing hoses from couplers, normally pull the hose straight out.

After hoses are removed, *be sure to insert dust plugs into the coupler ports*. Also place dust caps over the cylinder hose ends to protect them from dirt.

Bleeding Air From Remote Cylinders

Anytime a remote cylinder is plugged in the hydraulic circuit, all trapped air must be bled. This will prevent sluggish action of the cylinder.

1. First attach the cylinder to the circuit (see above).

CAUTION: For personal safety, have one person on the tractor operating hydraulic controls and a second person on the ground supporting the cylinder. Do not stand in front of or behind tractor wheels during this procedure.

2. Place the cylinder on the ground (or on a hanger) with the piston rod end down as shown in Fig. 16. (Or on mounted cylinders, place the head end of the cylinder in its working mount, allowing the rod end to move in and out freely.)

3. Start the machine and move the hydraulic control lever back and forth seven or eight times to extend and retract the cylinder. This will bleed the air. (On double-acting cylinders, you may have to turn the cylinder end-for-end and repeat the cycling of the control lever.)

CAUTION: Be sure machine is locked in PARK position before working around drive wheel.

DRAINING, FLUSHING AND FILLING SYSTEM

These services are recommended at least once each year for most machines.

Tools and Materials Needed

1. Containers for old fluid
2. Hydraulic fluid (for flushing, if needed)
3. Clean, lint-free cloths

Fig. 17—Bleeding Air From Remote Cylinder





- DRAIN SYSTEM PERIODICALLY
- SEE MACHINE OPERATOR'S MANUAL
- FREQUENCY VARIES WITH OPERATING CONDITIONS

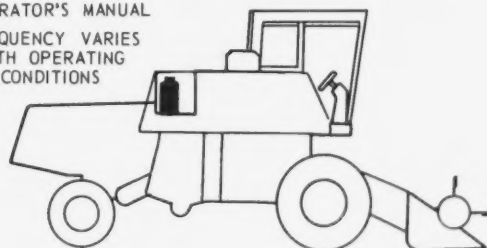
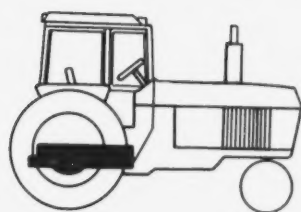


Fig. 18—Drain The System Regularly

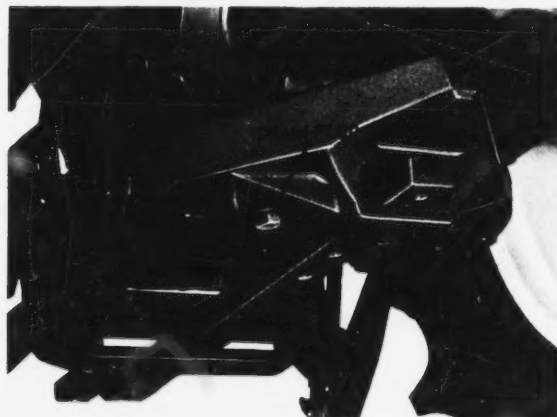
4. Box-end wrenches (inch or metric, as required)
5. Fresh hydraulic fluid (or type recommended)
6. Plastic tube (for bleeding)

Draining The Hydraulic System

Periodic draining of the entire hydraulic system is very important. This is the only positive way to completely remove contaminants, oxidized fluid, and other injurious substances from the system.

The frequency of draining depends on such things as the temperature of operation and the severity of working conditions. The operator's manual will tell the method to be used, and the frequency, depending on

Fig. 19—Transmission-Hydraulic System Drain Plug



conditions. Usually draining, flushing and refilling is recommended at least once each year.

Tools and Materials Needed

1. Wrenches for drain plug(s) and filter cap (inch or metric, as required)
2. Clean, lint-free cloths
3. Cleaning solvent (not gasoline)
4. New oil of type and grade recommended by manufacturer
5. New Filter
6. Container to catch waste oil

To drain the hydraulic system:

1. Operate the hydraulic system until it has reached normal operating temperature.
2. If the transmission case is the reservoir, also drive the machine until normal temperature is reached.
3. Remove drain plug from reservoir and catch oil in a container. See Figs. 9 and 18.
4. Replace drain plug.
5. If your operator's manual recommends flushing the system before refilling, refer to "Flushing The System," next.

Flushing The Hydraulic System

The nature and amount of deposits in a system may vary widely. Inspection may show any condition between a sticky, oily film and a hard, solid deposit (gum or lacquer formation) which completely chokes small oil passages.

If the system is drained frequently enough, the formation of gum and lacquer will be reduced.

When no gum or lacquer formation is suspected, clean the system as follows: After draining the system, clean any sediment from the reservoir, and clean or replace the filter elements.

It may be advisable to flush out the old oil remaining in the system after draining, particularly if the oil is badly contaminated. For this flushing, use the hydraulic fluid recommended for the system involved.

NOTE: Most solvents and chemical cleaners on the market today are NOT recommended for use in flushing hydraulic systems: 1) They are poor lubricants, resulting in damage to moving parts, especially the pump. 2) They are difficult to remove completely from the system. Just a trace of some of the commercial chlorinated solvents may be enough to break down the oxidation resistance of even the best hydraulic oils. Also, in the presence of a small amount of water, some of these solvents will corrode steel and copper.

To flush the system:

1. Operate the equipment to cycle the flushing oil through the system.

It is important that the valves be manipulated so that the new oil goes through all lines. The time necessary to clean the system will vary, depending on the condition of the system.

2. Run the oil through the system until inspection shows the equipment to be in satisfactory condition, or until it is obvious that the system will have to be disassembled and cleaned manually by a service shop.

3. Drain out the flushing oil and refill the system with clean hydraulic oil of the recommended type.

4. Clean or replace the system filters before refilling the system.

For details, see "Filling the System," next.

Filling The Hydraulic System

Before filling the system, clean or replace the hydraulic oil filter. The filter may be located in the transmission case (Fig. 20) or in a separate reservoir (Fig. 21).

Fill the system as follows:

1. Clean the area surrounding the filter cover before removing cover.
2. Remove the old filter and insert a new one (Fig. 20). Replace filter cover.
3. Fill the reservoir to the specified level with the recommended hydraulic oil. Use only clean oil and

Fig. 20—Typical Transmission-Hydraulic System Filter

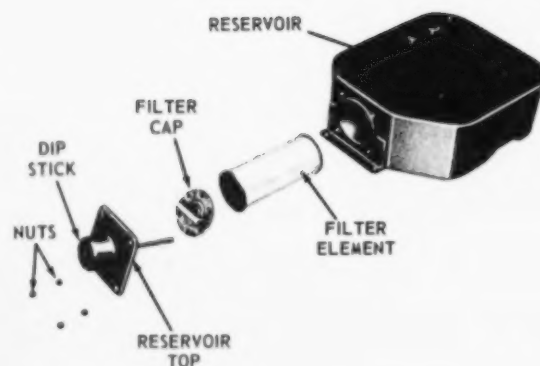
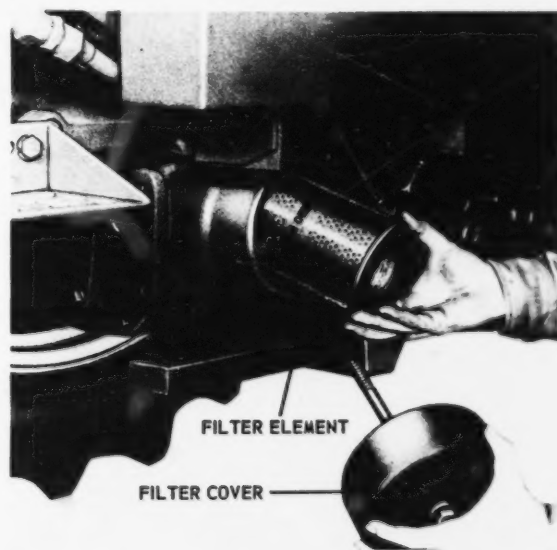


Fig. 21—Typical Hydraulic Oil Reservoir And Filter

funnels or containers. Be sure to replace the filler cap before operating the equipment.

4. Start the engine and warm up the hydraulic system. Then operate the equipment through its working cycle several times to bleed air from the system. (Hydraulic brakes and steering must also be bled individually—see following.)

5. Shut off engine and check oil level again. Add oil if necessary.

Bleeding Brakes

When the brake system is part of the hydraulic system, the brakes must be bled whenever the hydraulic oil is drained and replaced. Also, whenever the pedals feel spongy or have excessive pedal free travel, you must bleed the air from them.

We will describe the procedures for bleeding hydraulic brakes connected to the hydraulic system; for procedures concerning conventional hydraulic brakes (trapped oil type), refer to chapter 9, "Other Components."

The machine may be equipped with either *hydraulic* brakes or *power* brakes. Read the following paragraphs on bleeding each type.

Tools and Materials Needed

1. Wrenches (inch or metric, as required)
2. Screwdriver (if needed)
3. Transparent plastic tube (long enough to reach from bleed valve to transmission filler hole)

BLEEDING HYDRAULIC BRAKES

To bleed the brakes, proceed as follows:

1. Start the engine and run it at fast idle for two minutes to make sure the brake reservoir is filled with oil.

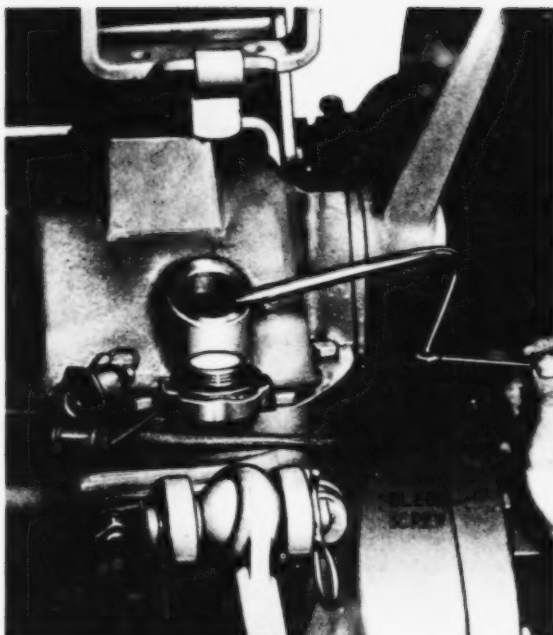


Fig. 22—Bleeding Hydraulic Brakes

2. Locate the bleed screws. Usually they are located on top of the axle housing near the differential.
3. Attach a transparent plastic tube to the bleed valve as shown in Fig. 22.
4. If possible, insert the other end into the transmission oil filler hole as shown. Be sure the end of the tube is submerged in oil.
5. Unscrew the bleed valve $\frac{3}{4}$ turn.
6. Slowly depress the brake pedal and allow it to return slowly.
7. Continue operating pedal in this manner until oil in the transparent tube is free of air bubbles.
8. With the brake pedal still depressed, close the bleed valve securely.
9. Remove bleed tube and repeat this procedure for the other brake.

BLEEDING POWER BRAKES

If reserve power for braking is provided by a hydraulic accumulator, check the accumulator before bleeding brakes. To check the accumulator, depress brake pedals firmly several times with the engine stopped. The pedal should feel firm for five or six applications. If any trouble is suspected, contact your dealer for service.

To bleed the brakes, proceed as follows:

1. Start the engine and loosen the bleed screw lock

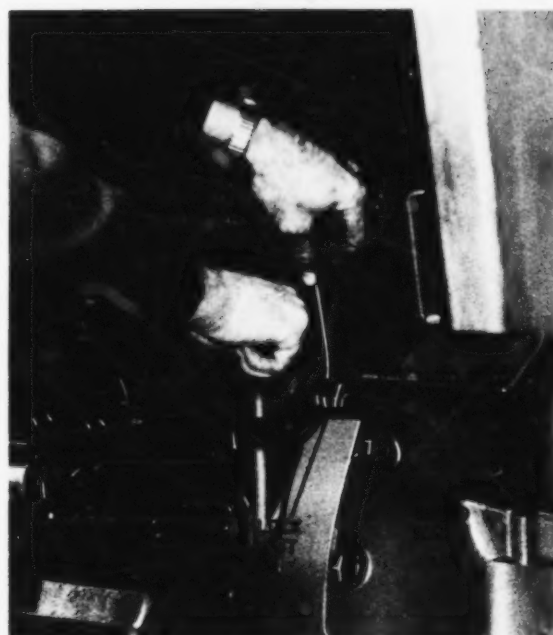


Fig. 23—Bleeding Power Brakes

- nut on both sides of the machine at the drive axle housing (Fig. 23), or follow instructions in your operator's manual.
2. Turn each bleed screw out two turns and tighten the lock nut. Tightening the lock nut prevents oil from leaking around the bleed screw.
3. Depress the brake pedals for a few minutes to bleed air from the brake system.
4. While holding the pedals down, loosen the bleed screw lock nuts and tighten the bleed screws.
5. Tighten the lock nuts, release the pedals and stop the engine.
6. Discharge the accumulator (if used) and check the pedal free travel. (The accumulator supplies oil pressure to apply the brakes for a short time after the engine has stopped.) If the travel is excessive (refer to your operator's manual), repeat the procedure again.
7. If bleeding the brakes does not correct the problem, take the machine to a service shop for testing and repair.

GENERAL MAINTENANCE OF HYDRAULIC SYSTEM

We have covered specific maintenance of the hydraulic system, now let's look at general maintenance:

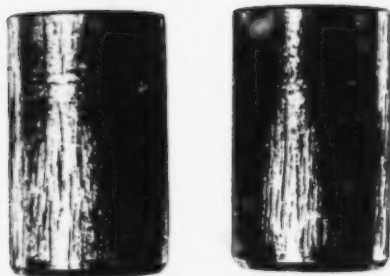


Fig. 24—Pump Pistons Scored By Contaminated Fluid

- Importance of Cleanliness
- Preventing Overheating
- Preventing Leaks
- Safety Rules

IMPORTANCE OF CLEANLINESS

Cleanliness is No. 1 when it comes to servicing hydraulic systems. **KEEP DIRT AND OTHER CONTAMINANTS OUT OF THE SYSTEM!** Small particles can score valves, seize pumps, clog orifices and so cause expensive repair jobs.

How do you keep the hydraulic system clean? Let's put it this way:

- *Keep the oil clean*
- *Keep the system clean*
- *Keep your work area clean*
- *Be careful when you change or add oil*

PREVENTING OVERHEATING

Heat causes hydraulic oil to break down faster and lose its effectiveness. This is why cooling of the oil is needed.

In many systems, enough heat is dissipated through the lines, the components, and the reservoir to keep the oil fairly cool. But on high-pressure, high-speed circuits, oil coolers are needed to dissipate the extra heat.

Overheating the system can:

- *Break down the oil*
- *Damage the seals*
- *Coat parts with varnish deposits*
- *Cause extra leakage past working parts*
- *Reduce the output of the system*

To help prevent overheating, keep the oil at the proper level, clean dirt and mud from lines, reservoirs, and coolers, check for dented or kinked lines, and keep relief valves adjusted properly. Also be careful not to

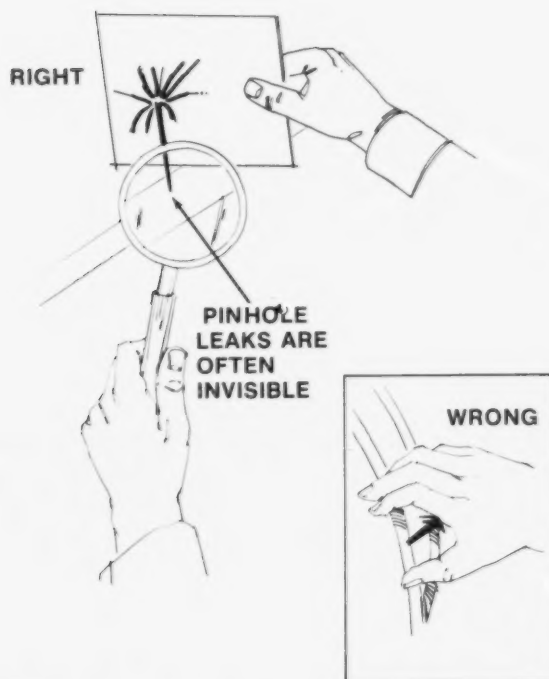


Fig. 25—Checking Oil Lines For Leaks

overspeed or overload the system and never hold control valves in power position too long.

If the system still overheats, take the machine to a service shop for testing.

PREVENTING LEAKS

What causes leaks? There are hundreds of causes, but leaks fall into two basic types:

- **External Leakage**
- **Internal Leakage**

Internal leakage does not result in actual loss of oil, but it reduces the efficiency of the system. External leakage does result in direct loss of oil and can have other undesirable effects as well.

External Leakage

External oil leaks not only look bad—they can be expensive and hazardous. A drop of oil every second from a leaking connector can cost you quite a lot of money.

A small leak can also be the signal for a hydraulic rupture that may injure a person as well as putting the machine out of operation.

Every joint in a hydraulic circuit is a potential point of leakage. This is why the number of connections in a system is kept to a minimum.

Components can leak, but care in assembly and use of new seals and gaskets during overhaul will help to reduce this problem.

The lines that connect the different parts of the system are the No. 1 source of external leaks. Here are a few key points:

1. If the reservoir oil level is lower than normal, check all external oil lines for leaks.
2. Pin-hole leaks are hard to detect, yet they can be dangerous. A "vapor" of oil from a small leak can create a fire hazard, or a fine spray of oil against a hot engine can ignite.

CAUTION: Do not expose bare skin to pin-hole leaks. Hydraulic fluid under pressure will pierce the skin, causing severe injury. Use eye protection and protective clothing when checking for pin-hole leaks. Hold a magnifying glass (Fig. 25) or a piece of cardboard or wood over the suspected area to protect yourself. If skin is accidentally punctured, see a doctor, experienced in hydraulic fluid injuries, at once.

3. The rubber cover on flexible hoses may crack or split without actually leaking. But check very closely for internal damage. The depth of the crack is the deciding factor. Any oil dampness is a sign the hose is leaking.

4. Air leaks in suction lines are hard to locate. One way is to pour oil over the points where you suspect leaks. If the noise or bubbling in the system stops, you've located the leak.

5. If line connections are leaking, *tighten only until the leak stops*. If the connection will not stay tightened, the threads are probably stripped and the connector must be replaced. If the connector will tighten but still leaks, check for a cracked line flare or a damaged seal. But remember: *More damage has been done to line connectors by overtightening than from any other cause.*

After stopping leaks in a system, be sure to warm up the system and cycle the equipment, then recheck the trouble spots to be sure the leaks are stopped.

Recheck the system oil level and replace any oil lost through leaks or broken connections.

Internal Leakage

Slight internal leakage as a thin oil film is built into the working parts of a hydraulic system. This lubricates the mating surfaces of valve spools, cylinder pistons, and other moving parts. Oil is not lost through this normal internal leakage since it eventually returns to the system reservoir.

However, too much internal leakage will slow the operation of the system and waste power through the generation of heat. In some cases, it may cause cylinders to creep or drift. Or it may cause loss of oil control in the valves.

Internal leakage increases with the normal wear of parts. Leakage is accelerated by using oil which has too low a viscosity because this oil thins faster at

higher temperatures. High pressures also force more oil out of leaking points in the system. This is one reason why excessive pressures can actually reduce the efficiency of the hydraulic system.

Internal leaks are hard to detect. Watch the operation of the system for sluggish action or creeping and drifting. When these signs appear, it's time to have a service shop test the system and pinpoint the trouble.

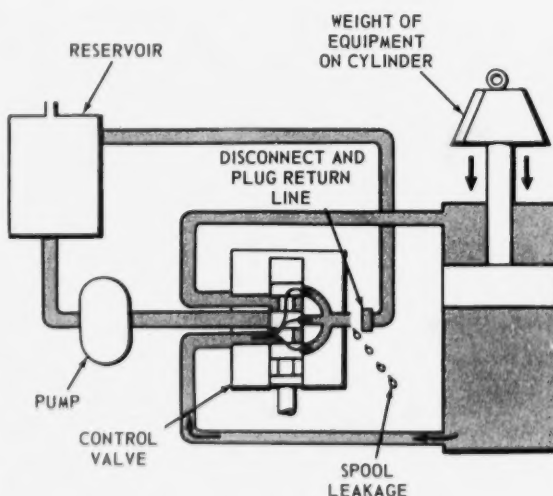
However, there are two components which can be checked without special hydraulic test equipment—the control valve, and the hydraulic cylinder.

Checking Control Valve For Internal Leaks

If you suspect the system control valve is leaking internally, make the following check.

1. Raise the hydraulic equipment a few feet off the ground, return the control lever to neutral and shut off the engine.
2. Notice whether the equipment settles toward the ground. If the equipment settles, temporarily support it and disconnect the return line between the control valve and reservoir, then plug the line (Fig. 26).
3. Remove the support and examine the open port in the control valve as the equipment settles. If oil leaks from the port, the control valve spool is leaking. Take the equipment to a service shop for repair.
4. Remove plug and connect return line to the valve again.

Fig. 26—Checking Hydraulic System Control Valve For Internal Leaks



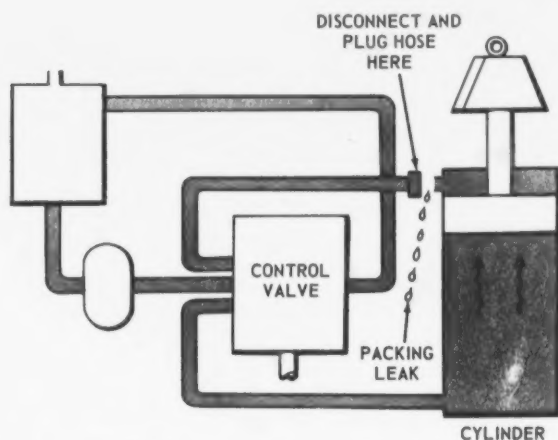


Fig. 27—Checking Double-Acting Cylinder For Internal Leaks

Checking Hydraulic Cylinder For Internal Leaks

If no oil is leaking from the control valve, check the cylinder as follows:

1. To check a double-acting cylinder, run the cylinder to one end of its stroke. Support the equipment if it is raised, then shut off the engine.
2. Remove the hose from the end of the cylinder that was not pressurized (Fig. 27).
3. Start the engine again, pressurize the cylinder, and see if any oil comes out of the open port.
4. Repeat the test in the opposite direction since it may be possible for the cylinder to leak in only one direction.
5. If oil leaks out the open cylinder port, the packings in the cylinder must be replaced. Take the cylinder to a service shop for repair.

TESTING HYDRAULIC SYSTEMS

If you cannot locate troubles with the operational checks above, the system can be checked using a hydraulic analyzer or test gauges. Using this equipment, you can accurately measure oil flow, pressure, and temperature, and quickly isolate faulty components.

WHAT A HYDRAULIC TESTER DOES

Hydraulic analyzers are available with pressure loading valves, pressure gauges (high and low pressure), flow meters, and temperature gauges to precisely analyze a complex hydraulic system. The test kit shown in Fig. 28 is one example.

In testing any hydraulic circuit, the following four checks are of prime importance:

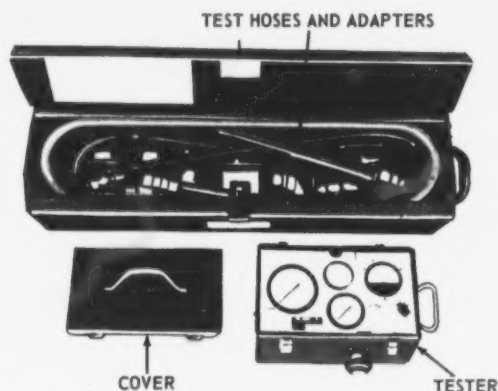


Fig. 28—Complete Hydraulic System Test Kit

1. **Temperature**—The oil should be checked for correct operating temperature to assure accuracy of the tests that follow.
2. **Flow**—The flow check determines if the pump is developing its rated output.
3. **Pressure**—These checks test relief valves for proper operation. (In a closed-center system, pressure checks indicate the operation of the main pump.)
4. **Leakage**—The leakage test isolates leakage in a particular component.

These basic checks may be made with most hydraulic testers. Before beginning, however, read the *instruction manual* furnished with the tester and review the system. You should have a thorough knowledge of the machine's specifications (relief valve pressures, pump output, engine rpm, and operating temperature) to accurately test the system.

To test a machine, you must disconnect some of the oil lines. But remember, **DIRT IS THE WORST ENEMY OF A HYDRAULIC SYSTEM**. Before disconnecting oil lines, steam clean the machine. And be sure to plug all openings to keep out dirt.

PUMP TESTING

The pump is the generating force for the whole hydraulic system. This is the place to start testing the system.

Installing The Hydraulic Tester

1. Relieve any pressure in the system and disconnect the pressure line between the pump and the control valve. Attach the pressure line to the hydraulic tester INLET port (Fig. 29).

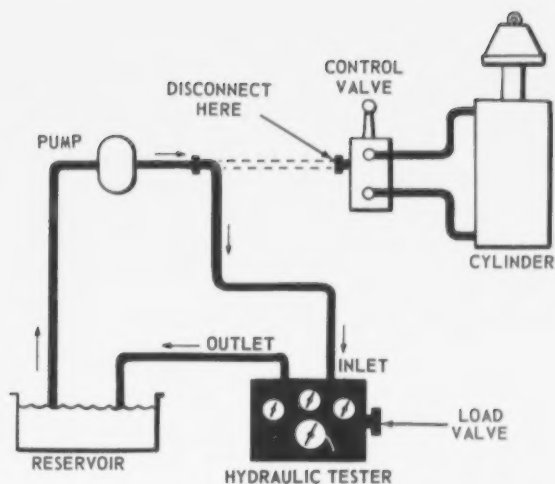


Fig. 29—Testing The Hydraulic Pump

2. Connect hydraulic tester OUTLET port to the reservoir. Whenever possible, connect directly to the reservoir return line because it usually has a return filter. On a closed-center system, always return hydraulic tester oil to a point between the main hydraulic pump and the charging pump to maintain pressure in the system (or to be sure the main pump does not lose its charge).

3. Check the oil level and slowly close the tester load valve to load the system. (Do not exceed the system's maximum rated pressure.) Continue loading until the normal operating temperature of the system is reached (see machine specifications).

Be sure the tester load valve is OPEN before starting any tests. The load valve can develop tremendous pressure on a component if it is closed too far.

Operating The Hydraulic Tester

1. With the tester load valve open, record maximum pump flow at zero pressure.
2. Slowly close the load valve to increase pressure and record the flow at 250 psi (1725 kPa) increments from zero pressure to maximum system pressure. Write down your test results so you can refer to them later. Use a test form such as the one shown in Fig. 30.
3. Open the hydraulic tester load valve until maximum pump flow is again at zero pressure.
4. Shut off the engine.

Pump Test Diagnosis

Pump flow at maximum pressure should be at least 75 percent of pump flow at zero pressure. (On modern variable displacement pumps of the radial piston type, 90 percent can be expected.) A lower reading like the one shown on the form in Fig. 30 indicates a badly worn pump.

If pump flow is poor during the free flow test as well as the pressure tests, the pump probably is not getting enough oil. This problem could be caused by low oil supply, air leaks, a restricted pump inlet line, or a dirty reservoir, filter or breather.

If the pump tests okay, then start checking the system components for trouble.

Fig. 30—Sample Form For Recording Pump Test Results (Hand-Written Figures Are Gallons And PSI)

OWNER _____		SERIAL NO. _____									
TRACTOR MODEL _____		EQUIPMENT _____									
COMMENTS _____											
		GALLONS PER MINUTE (LITERS / MINUTE) @ PSI (kPa)									
		0	250	500	750	1000	1250	1500	1750	2000	2250
PUMP TEST		31.0	28.0	25.0	22.0	19.0	16.0	13.0	10.0	7.0	
CIRCUIT TEST	DIRECTION-CYLINDER TRAVEL										

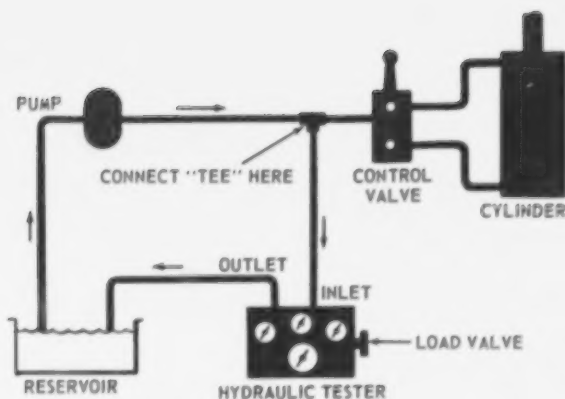


Fig. 31—Testing The System Components

SYSTEM TESTING

Check the system components by the following procedures.

Installing The Hydraulic Tester

Install a tee fitting in the line between the pump and the control valve and attach the hydraulic tester IN-LET port to this tee (Fig. 31).

Leave the return line from the hydraulic tester OUT-LET port connected in the same way as it was for the pump test.

Operating The Hydraulic Tester

1. Open the hydraulic tester load valve.
2. Start the engine and adjust it to the manufacturer's recommended operating speed.
3. Slowly close the hydraulic tester load valve to load the system. Continue loading the system until normal operating temperature is reached.
4. Open load valve to record maximum system flow at zero pressure.
5. Operate the control valve and hold it in one of its power positions.
6. Slowly close the hydraulic tester load valve and record flow in 250 psi increments from zero pressure to maximum system pressure (Fig. 31).
7. Open the load valve until maximum flow is again at zero pressure and repeat the test in the rest of the control valve power positions.

Be sure to make all the tests at the same oil temperature to get readings that can be compared. If oil is too hot from the previous test, allow it to circulate through the system for cooling.

System Test Diagnosis

Here's how to judge the system tests:

1. If flow at each pressure is same as for pump test: All components are okay.

Fig. 32—Sample Form For Recording System Test Results (Hand-Written Figures Are Gallons And PSI)

OWNER _____		SERIAL NO. _____									
TRACTOR MODEL _____		EQUIPMENT _____									
COMMENTS _____											
		GALLONS PER MINUTE (LITERS / MINUTE) @ PSI (kPa)									
		0	250	500	750	1000	1250	1500	1750	2000	2250
PUMP TEST		32.0	31.7	31.4	31.0	30.6	30.2	29.8	29.3	28.8	
CIRCUIT TEST	DIRECTION-CYLINDER TRAVEL										
Boom Circuit	Lower	32.0	31.7	31.4	31.0	30.6	30.2	29.8	29.3	28.8	
	Raise	32.0	31.7	31.4	31.0	30.6	30.2	29.8	29.3	28.8	
Bucket Circuit	Dump	32.0	31.7	31.4	31.0	5.0	0.0				
	Roll-Back	32.0	31.7	31.4	31.0	30.6	30.2	10.0	0.0		

2. If pressure begins to drop before full load is reached: One of the circuits is bad. (Such as the bucket roll-back circuit in Fig. 32.)

The pressure drop is caused by leakage. To find out whether the leakage is in the control valve or the cylinder, disconnect the cylinder return line and move the control valve to a power position. If oil leaks from the cylinder return port, the cylinder is at fault and must be repaired. If no oil leaks out, the control valve is probably at fault.

3. If flow drops the same with the control valve in all positions: The system relief valve is probably at fault (see following). This condition could also indicate a leak in the control valve.

Relief Valve Diagnosis

If equipment with circuit relief valves is being checked, you can tell when the valves open because flow will suddenly drop about 3 gpm (11 Lpm) (or drop to zero gpm [Lpm] if a full-flow relief valve is used). Often the relief valves will start to "crack" open before they reach their full-pressure settings. This can be noted by comparing the pressure and flow rate readings made in the circuit test above. Any great decrease in flow rate in these valves indicates a faulty valve.

As a general rule:

Faulty SYSTEM relief valves will affect readings in all tests.

Faulty CIRCUIT relief valves will affect only pressure readings in the individual circuits.

SUMMARY: TESTING THE SYSTEM

The tests we have given you are only basic guidelines. Once you start testing actual machines, use your machine technical manual for detailed tests and test results. And remember that the best testing equipment has no value unless the person at the controls knows how to interpret the results.

SAFETY RULES FOR HYDRAULIC SYSTEMS

1. Always wear eye protection and proper clothing when doing maintenance work on hydraulic systems.
2. Always lower the hydraulic working units to the ground before leaving the machine.
3. Park the machinery where children cannot easily reach it.
4. Block up the working units when you must work on the system while raised. Do not rely on the hydraulic lift.
5. Never service the hydraulic system while the machine's engine is running unless absolutely necessary, as for bleeding the system.
6. Do not remove cylinders until the working units are resting on the ground or securely on safety stands or blocks. Also shut off the machine's engine.

7. When transporting the machine, lock the cylinder stops to hold the working units solidly in place.

8. Be sure all line connections are tight and lines are not damaged. Escaping oil under pressure is a fire hazard and can cause personal injury.

9. When washing parts, use a *non-volatile* cleaning solvent.

10. To insure control of the unit, keep the hydraulic system in proper adjustment.

CHAPTER QUIZ

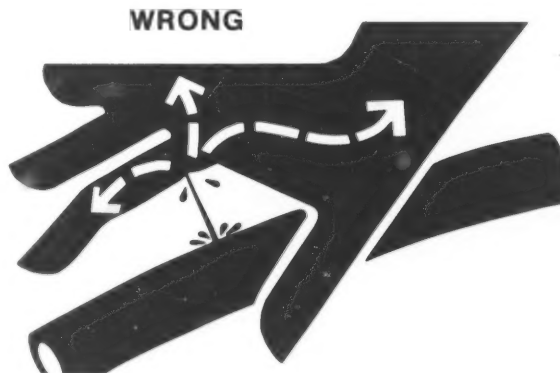
1. List three maintenance problems that concern a hydraulic system.
2. Match the symptom on the left with its cause on the right.

A. Oil bubbles or foaming oil	1. Water in the system
B. Change in oil level	2. Air leak somewhere in the system
C. Milky oil	3. Leaks in the external parts of the system
3. True or false? "Tighten leaking fittings as tightly as possible."
4. What is the biggest enemy of hydraulic systems?
5. Give one safety rule which you should follow to avoid injury to yourself or others from the hydraulic system.

AVOID HIGH-PRESSURE FLUIDS

Escaping fluid under pressure can penetrate the skin causing serious injury. Relieve pressure before disconnecting hydraulic or other lines. Tighten all connections before applying pressure. Keep hands and body away from pinholes and nozzles which eject fluids under high pressure. Use a piece of cardboard or paper to search for leaks. Do not use your hand.

If ANY fluid is injected into the skin, it must be surgically removed within a few hours by a doctor familiar with this type injury or gangrene may result.



9

Other Components





Fig. 1—Operator's Cab Protects You Against Adverse Operating Conditions

INTRODUCTION

We have covered maintenance of the major basic components of the machine. Now let's look at maintenance of these other components:

- **Operator's Cab**
- **Manual Steering**
- **Steering Axle and Wheels**
- **Manual Brakes**
- **Tires**
- **Grease Fittings**
- **Belt Drives**
- **Chain Drives**
- **Gear Drives**
- **Lighting and Electrical Accessories**

Failure to service these components can:

- *Cause premature wear or damage to the machine*
- *Make the machine unsafe to operate*
- *Make operation of the machine uncomfortable*

In addition, we will show how to clean the machine exterior, which should be done at least once each year.

To maintain each of the above components properly, you must be familiar with the basic services which are covered on the following pages.

OPERATOR'S CAB

The operator's cab is designed to protect you against dust, cold and heat. Most cabs today also protect you in roll-over accidents and help protect your hearing ability by reducing sound levels. Some even have radios and stereo tape players which give you up-to-date news or soothing music.

If the cab has fresh air ventilation, heating and air conditioning, you have environmental controls which protect you against adverse operating conditions.

Following are typical cab services that should be performed at least every 250 hours or at intervals recommended in your operator's manual to maintain the maximum comfort in the operator's cab:

- **Air Filters**
- **Heater**
- **Air Conditioner**

Let's look at the maintenance required for each of these.

FILTERS

The cab may be equipped with either a fresh-air filter,

a recirculating-air filter, or both (Fig. 2). Consult the operator's manual for detailed services.

Fresh-Air Filters

These are usually dry-type paper filters located in either the air intake or the filter cavity in the roof of the cab.

The following tools and materials are needed:

1. Compressed Air Source
2. Water Pressure Source
3. Container of Warm Water
4. Non-Sudsing Detergent

To clean **dry-type paper filter**:

1. Remove the filter from housing or access door (Fig. 2).
2. Tap the filter gently on a flat surface—dirty side down (Fig. 3).

Do not tap on uneven surfaces or the filter element may be damaged.

3. If you have a source of compressed air (not more than 30 psi; 205 kPa), direct it through the filter in the opposite direction of the air flow (Fig. 4). Air flow is usually indicated by arrows.

4. If the filter is still dirty, wash it as follows.

5. Soak the filter (Fig. 5) for 15 minutes in warm water (not over 100°F; 40°C) with a special dry filter

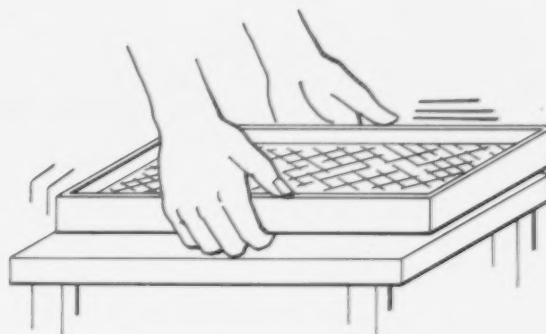


Fig. 3—Tapping Filter On A Flat Surface

element cleaner (or a nonsudsing detergent, such as used in a dishwasher).

6. Rinse until clean with water from a hose (not over 40 psi; 275 kPa).

7. Shake excessive water from the filter and allow it to dry. Do not use compressed air to dry filter because this will rupture the wet element.

8. Reinstall filter. Be sure to install it with the arrows pointing in the direction of air flow.

Recirculating Air Filters

These filters are usually made of urethane foam and are located in the air recirculators.

To clean **urethane foam filters**:

1. Remove filter (see Fig. 2) and clean by tapping or shaking filter.

Fig. 2—Air Filters In A Typical Cab



Fig. 4—Directing Air Through Filter In Opposite Direction Of Air Flow

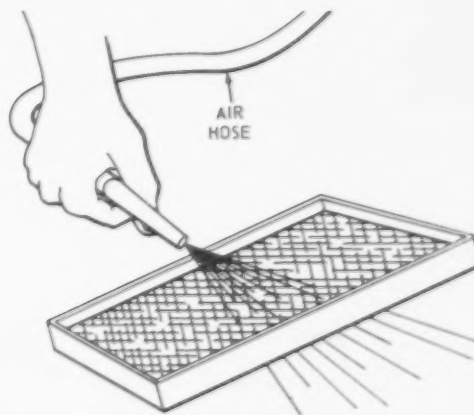




Fig. 5—Soaking Filter In Warm Water And Cleaner

2. If filter is still dirty, wash in clean water. Allow filter to dry thoroughly. Do not install wet filters in the air recirculators.

Fig. 7—Basic Air Conditioning System

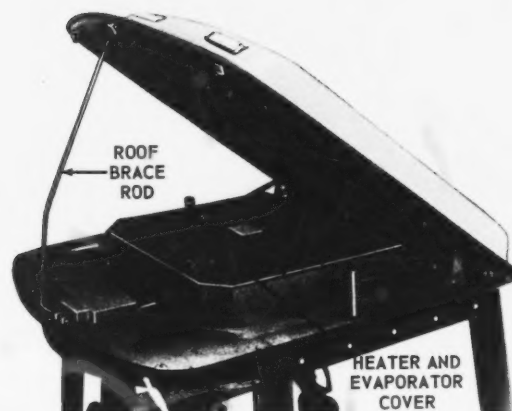
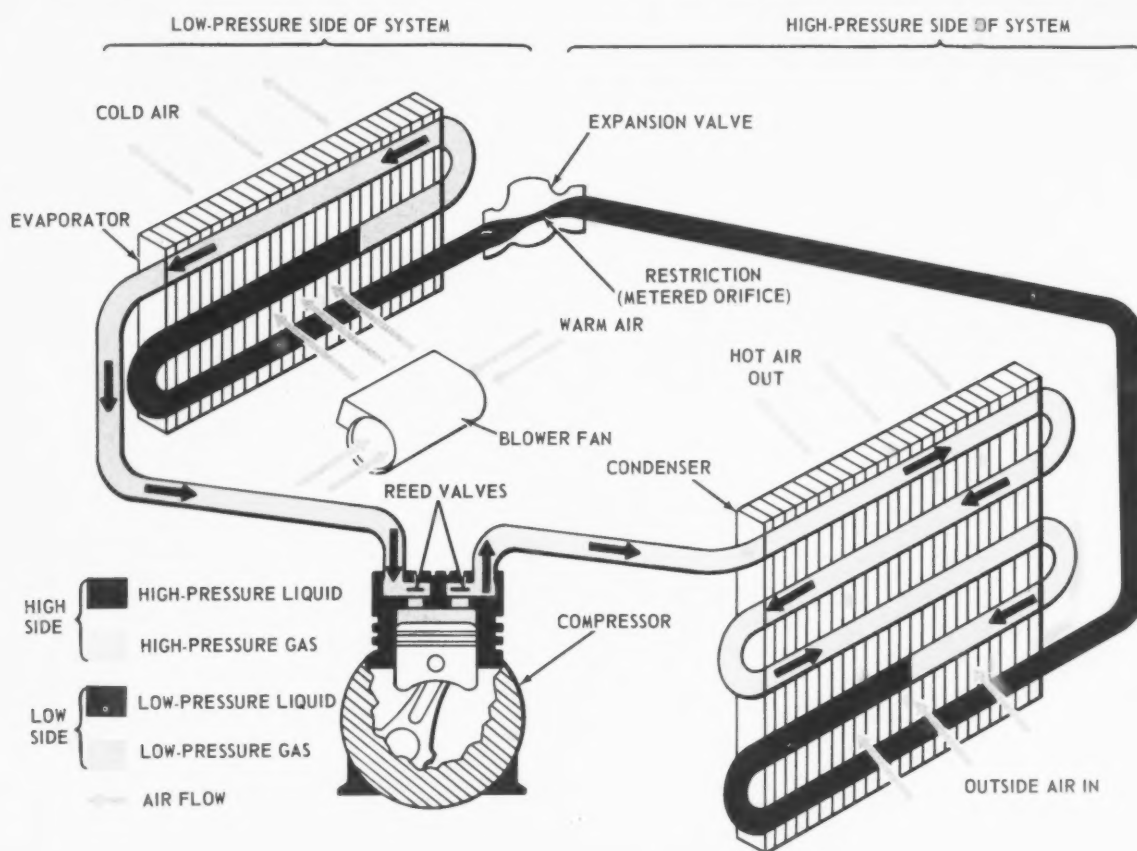


Fig. 6—Heater And Air Conditioner Evaporator Location

HEATER

The heater requires little maintenance. However, check the following:

1. Check the hoses and connections for leaks.

Tighten clamps or replace hoses if necessary.

2. Open roof and check accumulation of dirt and debris in heater core. Clean if necessary. You may have to remove a cover to gain access to the core (Fig. 6).

AIR CONDITIONER

Service the air conditioning system periodically to maintain maximum cooling.

In Fig. 7, note how the refrigerant cycle operates.

From the **compressor**, high-pressure gas is sent to the **condenser**, where it is converted to liquid and heat is dissipated. The high-pressure liquid flows on to the **expansion valve**, where it is metered and its pressure is reduced. At the **evaporator**, the liquid is again converted to gas, absorbing heat from the air. The cycle is then repeated, starting at the compressor.

The air conditioner is a heat transfer unit. Failure of any element will interrupt the heat exchange cycle and cause the whole system to fail. Each basic element is engineered and balanced to the other parts of the system in order to move heat from the inside air to the outside air, where it is dissipated.

Servicing Air Conditioner

Service the system as follows:

1. Check evaporator core for accumulation of dirt and debris (see Fig. 6). Clean if necessary.
2. Check condenser core for accumulation of dirt and debris. It must be clean. The condenser is usually located near the radiator (Fig. 8).
3. Check refrigerant level. A sight glass (Fig. 9) is usually provided near the receiver-drier for this purpose. Your operator's manual will tell where it is located.
4. The sight glass should be clear (free of bubbles)

Fig. 8—Air Conditioner Condenser Core

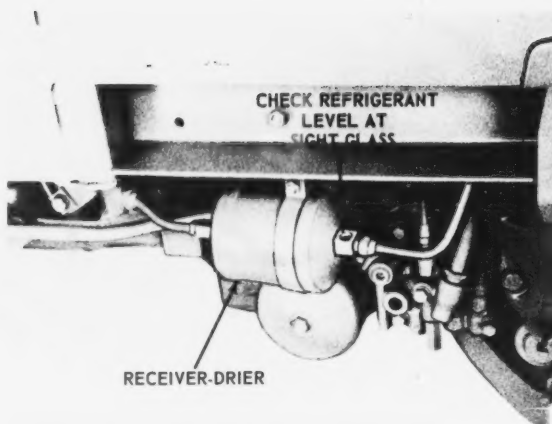
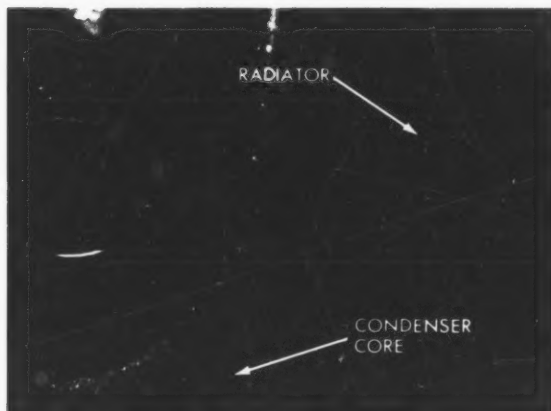


Fig. 9—Sight Glass For Checking Refrigerant Level

before starting the engine and operating the air conditioner.

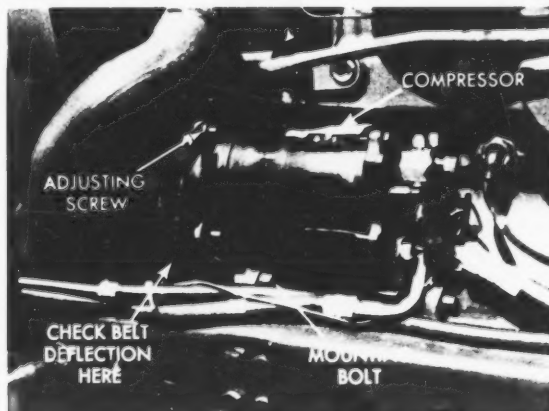
5. Start the engine and run it at fast idle.
6. Turn on the air conditioner to the highest speed and turn the temperature control to the coldest temperature.
7. Bubbles will appear in the sight glass for a few minutes after starting the air conditioner.

At temperatures above 70°F (21°C) the bubbles will disappear and the sight glass should be clear.

If the bubbles do not stop flowing, the refrigerant level is low. See your service shop for recharging the system. Special equipment and safety are vital to this service.

8. Check the compressor drive belt for tightness (Fig. 10).

Fig. 10—Compressor Belt Tension Adjustment



9. If the belt is too loose, tighten it as follows.
10. Loosen the compressor mounting bolt and adjusting cap screw (Fig. 10).
11. Apply an outward force to the compressor until the belt is tightened as specified (usually deflecting the belt $\frac{1}{4}$ inch [6 mm] with a 15- to 20-pound [65 to 90N] force on the belt midway between the compressor and crankshaft pulley is sufficient). See your operator's manual for exact specifications.
12. Tighten the compressor bolts in this position.
13. If water is not draining from the evaporator properly, check the evaporator drain tube trap (Fig. 11) for clogging or a dry trap.
14. If the water has evaporated from a trap, air will be drawn up the drain tube and may hold the condensed water in the evaporator housing. The trap must be primed. To do so, momentarily hold a garden hose against the bottom of the drain tube to fill the trap with water.
15. The receiver-drier (Fig. 9) is basically the filter for the air conditioner refrigerant. It removes condensation and other moisture, which can harm the system. While not replaced at regular intervals, it

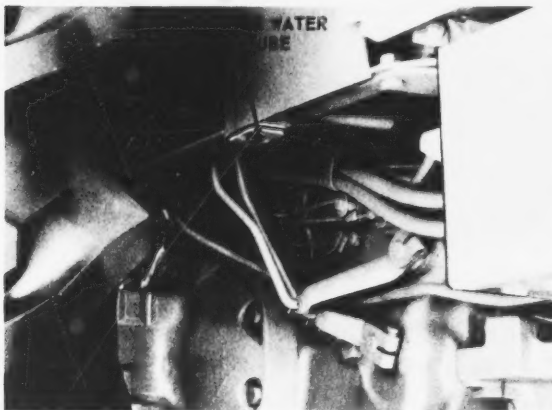


Fig. 11—Evaporator Water Drain Tube

should be replaced when the system is in for major service, or whenever excessive moisture is a problem in the system.

16. Compressor seals may dry out during cold weather when the air conditioner has not been operated for long periods of time. This will cause leaks which will allow refrigerant to escape. To avoid this problem operate the air conditioner for 5 to 10 minutes at a time at least once a month to prevent seals from drying out. If necessary, rotate the compressor crankshaft a few times by hand.

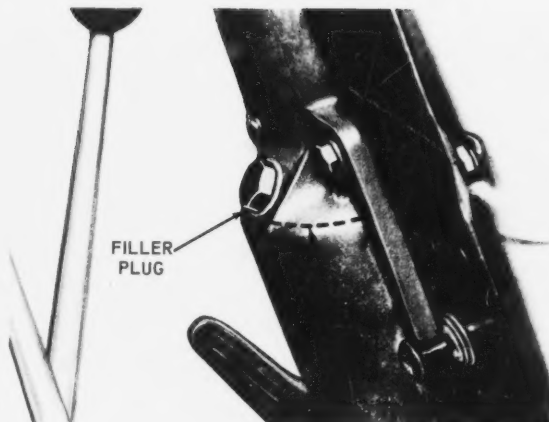


Fig. 12—Checking Manual Steering Gear Housing Oil Level

HEATING AND AIR CONDITIONING PROBLEMS

If the machine cab does not heat or cool properly after regular maintenance has been performed, take it to a dealer for testing and service. Special test equipment and service tools are needed, especially for air conditioners.

MANUAL STEERING

The only maintenance required for manual steering gear is maintaining the oil level in the gear case every 250 hours and adjusting the gear backlash.

CHECKING MANUAL STEERING OIL LEVEL

Check the oil level in the steering gear housing every 250 or 500 hours, as recommended (Fig. 12). The operator's manual will indicate the proper level and type of lubricant.

ADJUSTING STEERING BACKLASH

When steering wheel backlash or "play" becomes excessive, adjust it as follows:

1. Turn the steering wheel from one extreme to the other and count the number of turns.
2. Turn the steering wheel back one half the number of total turns. This will position the mechanism in the mid-position.
3. Loosen the jam nut on the steering gear adjusting screw (Fig. 13).
4. Tighten the adjusting screw until a very slight drag is felt when the steering wheel is turned back and forth through the mid-position.
5. Use a screwdriver to prevent adjusting screw from turning and tighten the nut. Recheck the adjustment.

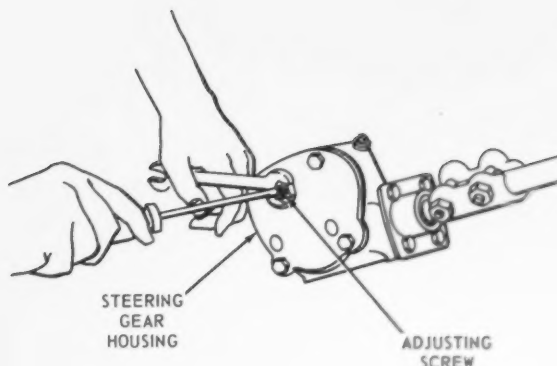


Fig. 13—Adjusting Steering Gear Backlash

STEERING AXLE AND WHEELS

The steering axle and wheels require periodic adjustment and lubrication to prevent excessive wear and "play." Also, when the steering wheels are guided by tie rods and steering arms, toe-in must be adjusted annually or more frequently if recommended.

LUBRICATING STEERING AXLE AND WHEEL BEARINGS

Some steering axles and wheels require lubrication every 10 hours of operation. The exception is hand-packed bearings. These must be disassembled, cleaned, and hand packed every 1000 hours or annually. Also, wheel bearings with grease fittings must be cleaned and hand packed at the same intervals. When operating in extremely wet or muddy conditions, these services should be done more often.

Shown in Fig. 14 is the location of grease fittings for typical steering axle and wheels. The operator's manual will show you where these are on the machine and how many strokes of lubricant to apply to each. Be sure to wipe fittings clean before applying grease gun.

CLEANING, REPACKING, AND ADJUSTING WHEEL BEARINGS

The following procedures describe typical cleaning, repacking and adjustment of most wheel bearings.

Tools And Materials Needed

1. Wrenches (inch or metric, as required)
2. Diagonal Pliers
3. Clean Cloths
4. Container Of Solvent (for cleaning, not gasoline)

5. Multipurpose Grease (or wheel bearing grease if recommended)
6. New Cotter Pins
7. Small Stiff-Bristle Brush
8. Hydraulic Jack
9. Support Stands
10. Source Of Compressed Air (if available)

Removing And Cleaning Bearings

Two typical types of wheel bearing assemblies are shown in Figs. 15 and 16. The spindle-type wheel is used on machines equipped with double tricycle wheels or wide axles. The axle-type wheel is usually used on machines with a single wheel.

REMOVING BEARINGS ON SPINDLE-TYPE WHEELS

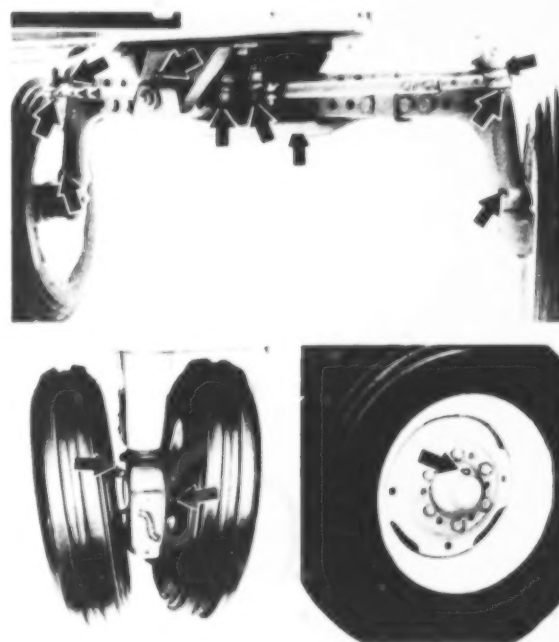
To remove the wheel bearings of a spindle-type wheel:

1. Jack up the machine so that the wheel is off the ground. Be sure to block the other wheels and set the parking brake so that the machine won't move and fall off the jack or support stands. Use blocks or support stands to securely support the machine. (On tricycle dual front wheels, run one wheel up on a block, freeing the other wheel for service.)

CAUTION: Never rely on the jack alone to support the machine. Always have blocking under the machine also.

2. Clean dirt from wheel and hub cap.

Fig. 14—Lubricating Grease Fittings On Steering Axle And Wheels (Wipe Clean First)



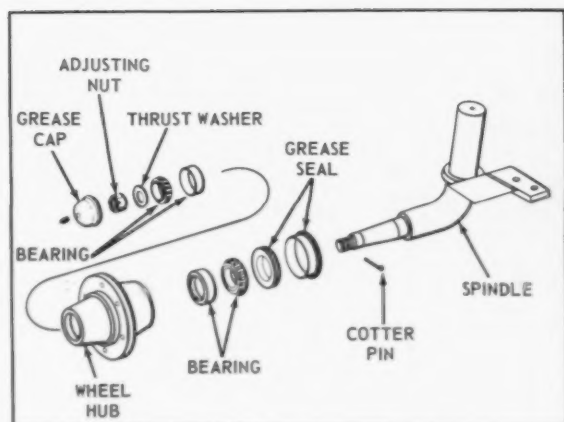


Fig. 15—Spindle-Type Wheel And Bearings

3. Remove hub cap. It may be either screwed in, bolted on, or pushed into the hub. If bolted on, be careful not to damage the gasket under it. Lay cap, gasket and other parts as they are removed, in a clean pan or container. Avoid laying parts on a dirty surface. Even the slightest amount of dust or dirt is difficult to remove from a bearing even in a cleaning solution.

4. Remove cotter pin with diagonal pliers. Straighten pin before removing it (Fig. 17).

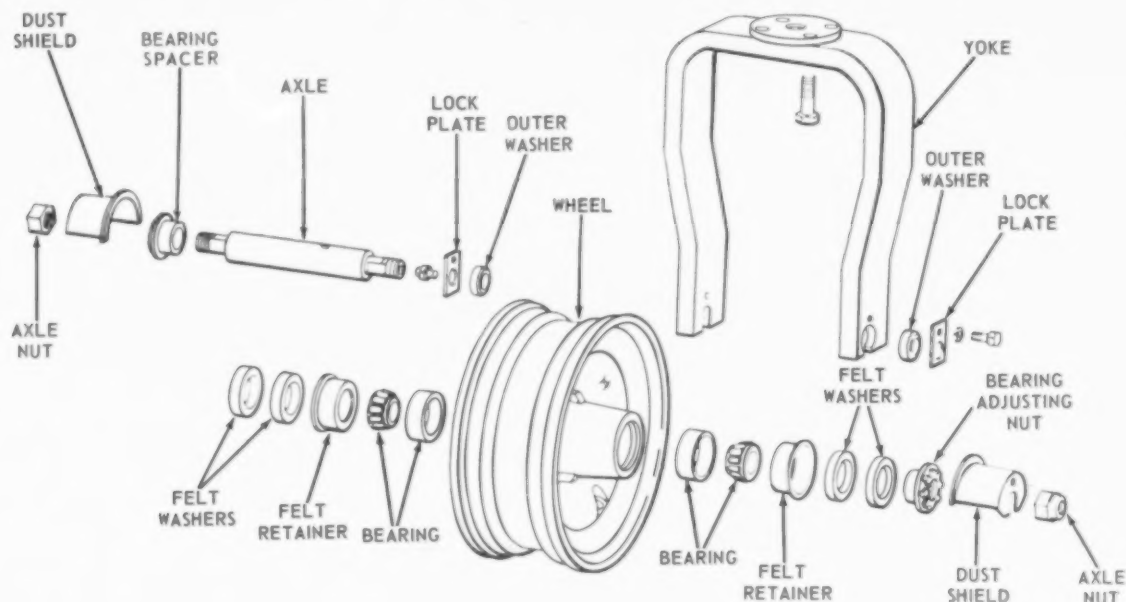


Fig. 17—Removing Adjusting Nut

5. Remove adjusting nut.

6. Remove thrust washer and outer bearing (Fig. 18). Shake the wheel gently if necessary to dislodge them. Do not allow the parts to fall to the ground.

Fig. 16—Axle-Type Wheel And Bearings



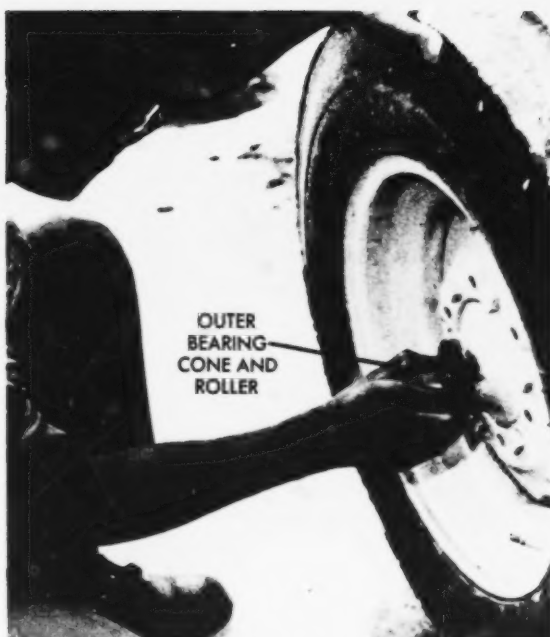
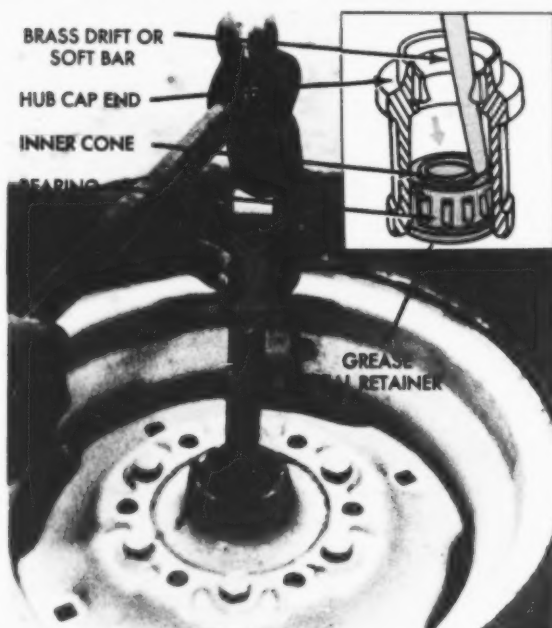


Fig. 18—Removing Thrust Washer And Outer Bearing

7. Carefully pull the wheel off the spindle. Hold your hand behind the wheel to catch the inner bearing if it should fall off when the wheel clears the spindle.

Fig. 19—Removing Inner Bearing And Grease Seal



On some wheels the bearing and seal will come off with the wheel or remain on the spindle. If the bearing and seal cannot be removed easily from the spindle, leave them on. They can be cleaned while on the spindle.

8. If the grease seal remained in the hub, remove it with your fingers. Then remove the inner bearing.

If the grease seal cannot be removed with your fingers, proceed with the next step as given below.

9. Turn the wheel over with the inner bearing down. Place a clean cloth or container under the hub to catch the bearing and seal when they fall out.

10. Use a brass drift punch or a wood dowel and gently tap the bearing cone from the hub (Fig. 19). Be careful not to tap on the bearing cage. You may damage the bearings.

Refer to cleaning the bearings later in this discussion.

REMOVING BEARINGS ON AXLE-TYPE WHEELS

To remove the wheel bearings of an axle-type wheel:

1. Jack up the machine and support it as described in step 1 above.

2. Clean dirt from the wheel and hub areas.

3. Remove the screws from the bearing lock plates and bend the lock plates away from axle nuts (see Fig. 16).

4. Loosen axle nuts and remove dust shields.

5. Remove axle nuts and outer washers. Be careful that the wheel does not fall on you when you remove these parts. The wheel should now come off the yoke easily. Push down on the wheel if it does not come loose.

6. Disassemble axle, seals (felt washers and retainers), bearings, and any spacers and nuts remaining.

CLEANING WHEEL BEARINGS

To clean the wheel bearings and other parts:

1. Swirl the bearing in a container of clean solvent, using a brush to loosen grease deposits.

If you were unable to remove the inner bearing (spindle-type wheel), clean it and the grease seal while in place. Use a large brush and hold the container of solvent under the parts (Fig. 20). Dip the brush in the container and wash the bearing and seal thoroughly.

2. Clean the bearing cups also. It is not necessary to remove the cups from the hub. Also, clean the hub, cap and spindle or axle.

3. Remove solvent from all washed parts. If dry compressed air is not available, use a cloth free of dirt, dust and lint. Hold the bearings so the air blast won't spin the rolling elements or the cage (Fig. 21). Spinning a dry bearing can cause minute scoring of the bearing surfaces which will provide a rough enough surface to cause rapid wear.



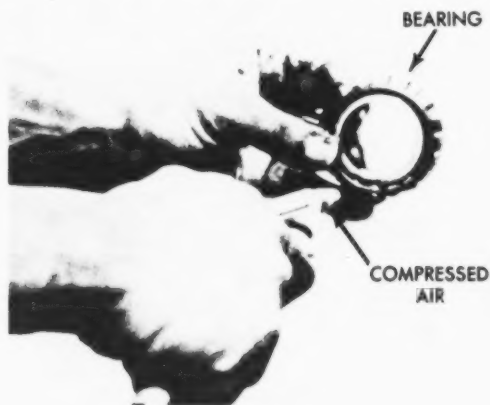
Fig. 20—Cleaning Inner Bearing On Spindle

NOTE: Do not use air which contains moisture. Moisture will cause the bearings to rust in a very short time.

4. Examine bearings for damage, wear, rust or corrosion. If it is apparent that any of these defects are serious enough, replace both the bearing race and cup of the affected bearing.

If the inner bearing (spindle-type wheel) requires replacement and you were unable to remove it before, use a wood dowel and hammer to tap off the bearing.

Fig. 21—Drying Bearing With Compressed Air



5. Inspect the grease seals and retainers for excessive wear or damage. Replace any defective seals. The seal keeps out the dirt and moisture as well as retaining the grease.

If the seal is defective, the bearing life will be short. It is a good practice to replace seals and retainers each time the bearings are cleaned and repacked.

After you have determined which bearings can be re-used and have replaced those that cannot, you are ready to repack the bearings.

Repacking And Assembling Bearings

To repack the bearings with grease and reassemble the wheels:

1. Use multipurpose grease or wheel bearing grease as specified by your operator's manual.

2. Rub a thin coating of clean crankcase oil on your hands to prevent the grease from sticking to them.

3. Place a small quantity of grease in the palm of your hand (Fig. 22). Push the grease into the elements of the bearing, press the bearing against the grease and rotate the bearing until grease has worked into the bearing thoroughly. Repeat this for each bearing.

4. If the inner bearing was left on the spindle, apply a thick coating of grease to the outer portions of the bearing. Wrap a clean cloth or piece of plastic around the bearing. Twist the ends of the cloth or plastic until it binds tightly around the bearing. This will press the trapped grease into the bearing (Bearing packer will do an even more thorough job, if available.)

Fig. 22—Packing Grease Into A Bearing



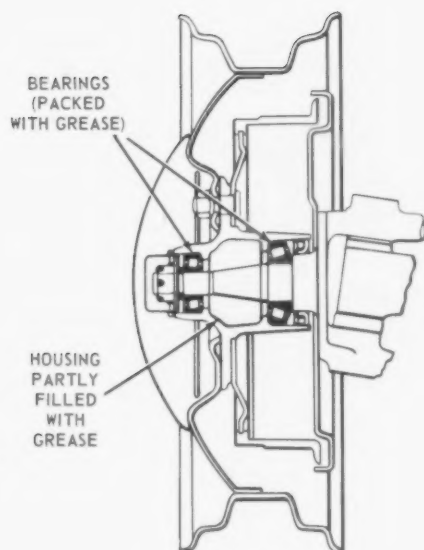


Fig. 23—Wheel Hub Housing Partly Filled With Grease

5. Apply a coating of grease to the inside of the hub. This will help to prevent rust and prevent the entrance of dirt and water. Do not fill the entire cavity of the hub unless the operator's manual recommends it. Air space should be left in most hubs to permit the air to expand without building up pressure which can force grease past the seals (Fig. 23).

6. Reassemble the wheel bearings in the reverse order of disassembly. Be sure that grease seals are seated in the hub or retainers properly.

7. Install the wheel and be careful that dirt does not get into the bearing grease.

8. Adjust the wheel bearings as follows.

Adjusting Spindle-Type Wheels

1. Install thrust washer and slotted adjusting nut.

2. Tighten slotted adjusting nut until bearing is seated properly (Fig. 24). Be sure bearings are aligned with the spindle.

3. Loosen the adjusting nut until the wheel can be turned easily; then turn the wheel and tighten the nut again until the wheel begins to turn with a slight drag.

NOTE: Some manufacturers recommend tightening the adjusting nut to a specific torque. You must use a torque wrench for this adjustment.

4. Loosen the adjusting nut until the nearest slot is aligned with the hole in the spindle. Check your operator's manual for its recommendations. Some manufacturers suggest loosening the nut as much as 1/6 to 1/3 turn.

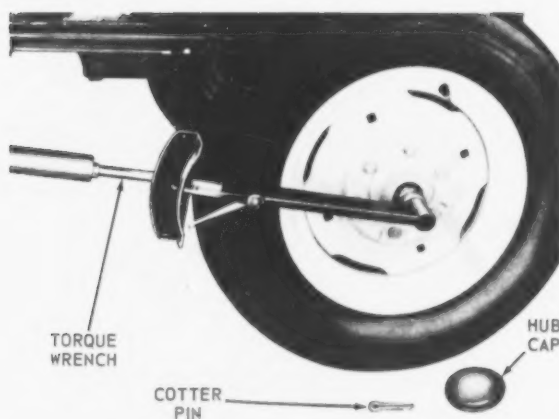


Fig. 24—Adjusting Wheel Bearings On Spindle-Type Wheels

5. Insert a *new cotter pin* if available. Use diagonal pliers and bend one leg of the pin over the end of the spindle. Cut off any excess length of the other leg and bend it back against the nut. If the cotter pin is not installed properly, it could loosen and fall out. Then the wheel can come off.

6. Replace the hub cap.

Adjusting Axle-Type Wheels

1. Install the wheel on the yoke.

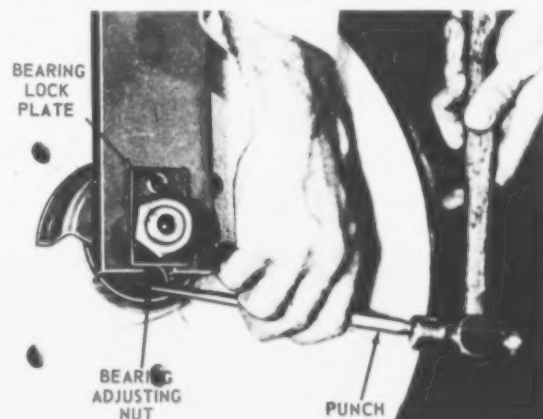
2. Slide outer washers onto axle until they seat into the hole in the yoke.

3. Attach the lock plates loosely with cap screws.

4. Screw on the axle nuts loosely.

5. Tighten the bearing adjusting nut with a drift and a hammer (see Fig. 25) until a slight drag is felt when the wheel is rotated.

Fig. 25—Adjusting Wheel Bearings On Axle-Type Wheels



6. Back the nut off and lock the adjustment in the closest notch with the lock plate screw.
7. Tighten the axle nuts. The wheel should still rotate with a slight drag.
8. If the adjustment is correct, bend the corner of the lock plates against the axle nuts.

ADJUSTING WHEEL TOE-IN (WIDE AXLE MACHINES)

Wheels which steer the machine must have proper toe-in so that the machine tracks in a straight line. This reduces wear on the tires and makes steering easier.

With wide steering axles, wheel toe-in must be checked periodically. "Toe-in" means that the wheels point slightly inward on the front or leading side.

Check the toe-in whenever:

- *Steering becomes difficult*
- *After hitting an obstacle*
- *After changing wheel spacing*
- *Before operating the machine at the beginning of the season.*

Checking And Adjusting Wheel Toe-In

To check the toe-in of the wheels which steer the machine:

1. Drive the machine straight ahead for a short distance on level ground. Stop the machine and shut off the engine.

Fig. 26—Measuring Wheel Toe-In

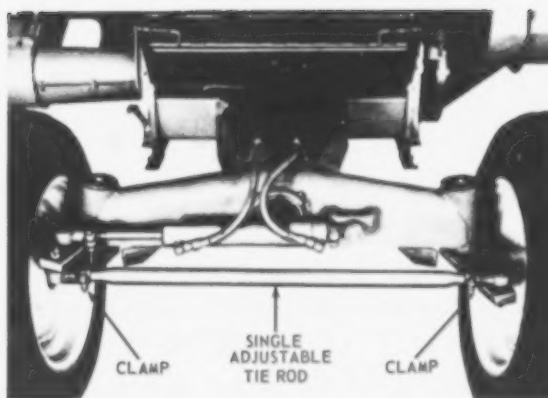
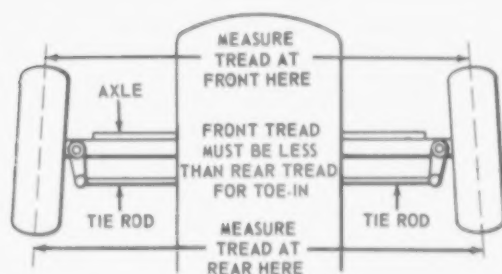


Fig. 27—Machine With Single Tie Rod Adjustment

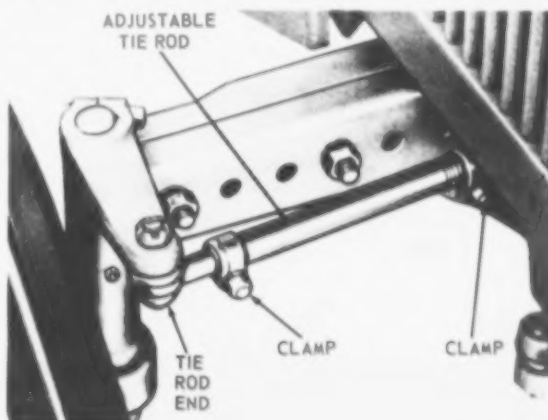
2. Measure the wheel tread at the front and rear of the wheels at hub level (Fig. 26). Usually, proper toe-in is $\frac{1}{8}$ to $\frac{3}{8}$ inch (3 to 10 mm) less in the front than in the rear. Check the operator's manual for specifications.

If toe-in does not measure correctly, proceed with the following steps.

3. On machines with a single tie rod between steering wheels, loosen the tie rod clamps and turn the tie rod until the measurements are correct (Fig. 27). Tighten clamps.

4. On machines with a tie rod for each wheel, loosen both clamps on each tie rod (Fig. 28). Turn each tie rod an equal amount until toe-in measurements are correct. Tighten clamps. Both wheels must have equal toe-in.

Fig. 28—Machine With Tie Rod For Each Wheel



BRAKES

Most machines have two brake pedals (Fig. 29) which may be used for stopping (both pedals) or for turning (one pedal on either side to help turn machine).



Fig. 29—Most Machines Have Two Brake Pedals

To keep the machine safe to operate, be sure to maintain the brakes properly. Brakes that are out of adjustment can cause uneven braking or poor braking which may cause your machine to overturn or crash into something, injuring you or others and damaging the machine.

Fig. 31—Hydraulic Brakes

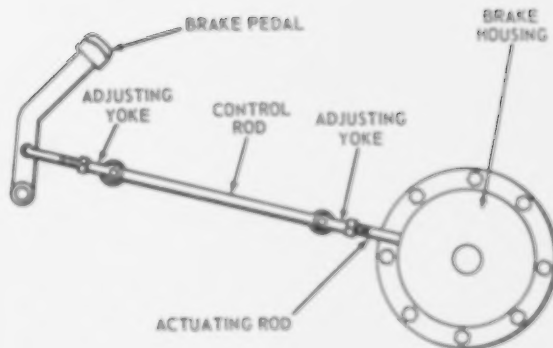
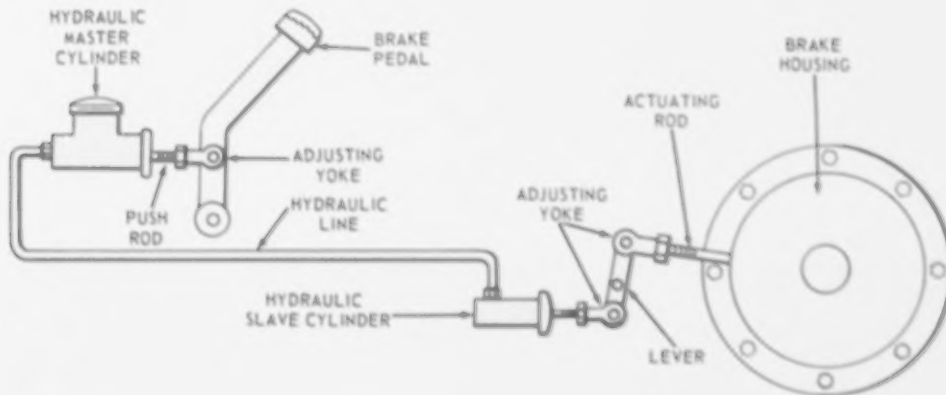


Fig. 30—Mechanical Brakes

Knowing how brakes work will help you understand why they need adjustment.

OPERATION OF BRAKES

The machine may be equipped with mechanical brakes, hydraulic (power) brakes, or hydraulic (trapped oil) brakes. Hydraulic powered brakes were discussed in Chapter 8; here mechanical and hydraulic (trapped oil) brakes will be described.

Almost all agricultural machines have brakes for the drive wheels or drive train only.

Mechanical brakes are controlled and actuated by mechanical linkage. Control rods or cables provide the linkage between the brake pedals and the wheel brakes (Fig. 30).

Thus far, only the brake controls have been described. The braking action itself is provided by one of the following methods:

- **Band Brakes (external contracting)**
- **Shoe Brakes (internal expanding)**
- **Disk Brakes**

For more information on hydraulic brakes, see Chapter 8.

Hydraulic brakes are controlled and actuated by hydraulic oil trapped between the brake master cylinder (controlled by the brake pedals) and the slave cylinders, which actuate the brake mechanism (Fig. 31).

The braking action of **BAND BRAKES** is obtained by pulling the band tightly around a rotating drum. When the force is released, a spring retracts the band so that the drum can rotate freely (Fig. 32).

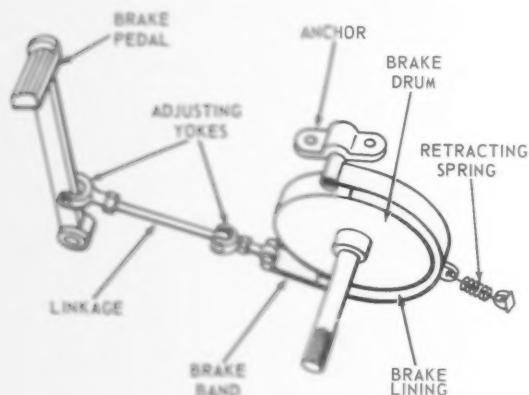
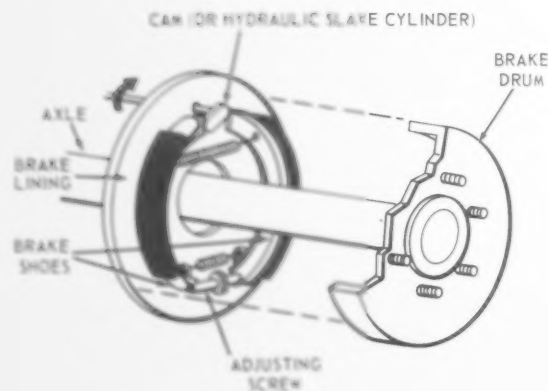


Fig. 32—Band Brakes

The **SHOE BRAKE** is forced against the inside of the brake drum and slows or prevents the drum from turning (Fig. 33). This type of brake is popular on automobiles.

Fig. 33—Shoe Brakes



DISK BRAKES are commonly used on agricultural machines; although, the other two types are found on some machines. Each brake mechanism consists of two driven brake disks which have friction facings attached to each side and two actuating disks which force the brake disks against a stationary braking surface (Fig. 34).

The driven brake disks are attached to either differential input shaft or to each drive axle within the differential housing.

Between the brake disks are two actuating disks which are held together by springs. Three steel balls are located in tapered cups on the inside of each actuating disk. When the actuating disks are rotated in opposite directions by levers, the steel balls ride out of their cups and force the brake disks apart (Fig. 34, right).

As the brake disks are forced farther apart, they bind against the stationary braking surfaces of the housing and slow or stop the shaft from turning.

All three of these brakes may be controlled by either mechanical or hydraulic action.

ADJUSTING THE BRAKES

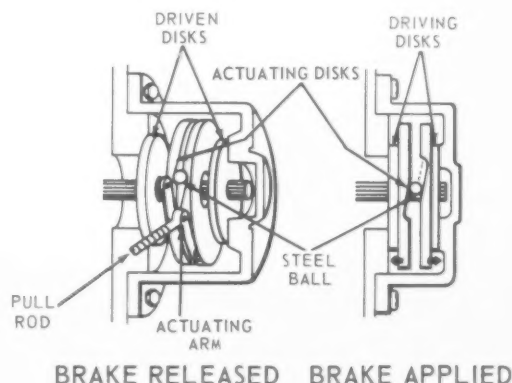
Two things can indicate when brakes need adjustment:

1. *Too Much Pedal Free Travel*
2. *Poor Or Uneven Braking Action*

Typical adjustments are made as follows:

Before attempting to adjust the brakes on your machine, jack up the machine until the drive wheels clear the ground (Fig. 35). Support the machine securely with stands or blocks. Block the other wheels to prevent the machine from rolling off the supports. Be very careful. You could be seriously injured if the machine should fall off the supports.

Fig. 34—Disk Brakes



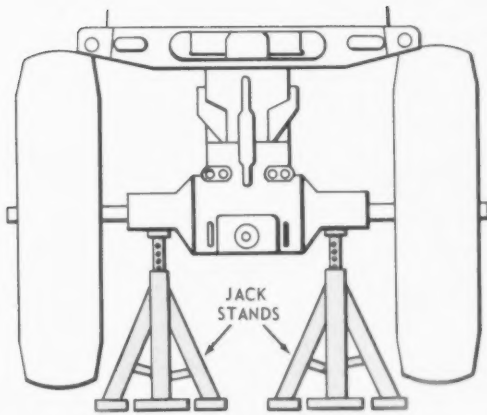


Fig. 35—Raising Drive Wheels Off Ground

CAUTION: Do not use concrete or cinder blocks to support machines as they are liable to crack or break, causing the machine to fall.

Tools And Materials Needed

1. Jack
2. Support Stand Or Blocks
3. Wrenches (inch or metric, as required)
4. Screwdriver
5. Ruler (inch or metric, as required)
6. Brake Fluid
7. Clean Cloth

Adjusting Mechanical Disk Brakes

To adjust disk brakes:

1. Adjust brake pedal free travel (Fig. 36) at either the pedal or the brake housing, whichever is recommended in your operator's manual (see Figs. 30, 31 and 32).

If the brake pedals have an interlock (Fig. 37) latching them together, adjust the pedal with the interlock first. Before adjusting, you must loosen a lock nut on the brake linkage at either the brake pedal or the brake housing.

2. Tighten or loosen the adjusting nut or yoke until the recommended free travel is obtained.

3. Repeat this procedure for the other brake pedal. This pedal must have the same amount of free travel as the other so that each pedal will cause the same amount of braking action when the pedals are interlocked. You must adjust brake pedals that are separated from each other in the same manner.

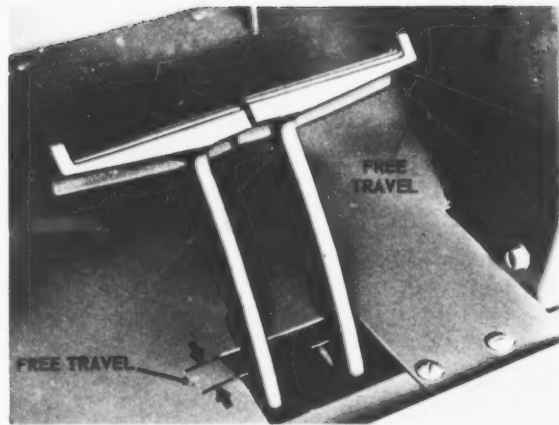


Fig. 36—Two Methods Of Measuring Pedal Free Travel

4. Check brakes for equal braking action while the machine is still raised off the ground (Fig. 38).
5. Latch the brake pedals together (Fig. 37).
6. Start the engine and run it at medium throttle. Check to be sure no one is near the machine.
7. Shift the transmission into a medium speed range and engage the clutch slowly to start the wheels rotating.

Fig. 37—Brake Pedal Interlock



8. Disengage the clutch and shift into neutral.

9. Apply the brakes slowly and observe the rate the wheels rotate (Fig. 38). If one wheel slows before the other, adjust the brakes until the two wheels brake evenly.

10. If the brakes cannot be adjusted evenly, new brake linings may be needed.

Adjusting Mechanical Shoe Brakes

To adjust shoe brakes, the machine should be on supports, drive wheels off the ground (see Fig. 38) then proceed as follows.

1. Remove the adjusting slot cover from each wheel cover (inside of wheel).

2. Insert a screwdriver into the slot to engage the adjusting screw teeth (Fig. 39).

3. Turn the adjusting screw until the wheel drags as you rotate it by hand. Back off the adjusting screw until little or no drag is felt. Repeat for the other wheel. Be sure to adjust it the same.

4. Check brake pedal free travel according to your operator's manual. If it isn't correct, adjust it by shortening or lengthening the linkage as required. Be sure that both pedals have exactly the same free travel.

5. Check the brakes for equal braking action while the machine is still off the ground. Follow the procedures described above for disk brakes, steps 5 through 11.

Fig. 38—Checking For Equal Braking Action

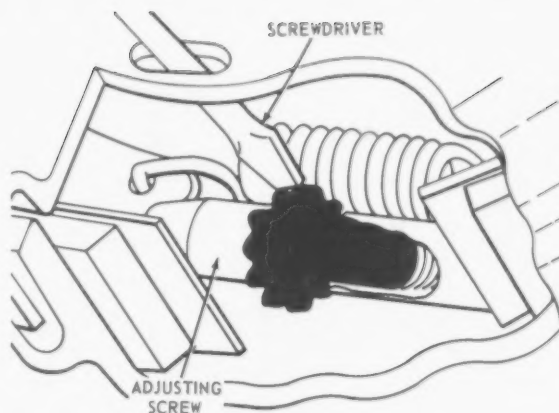
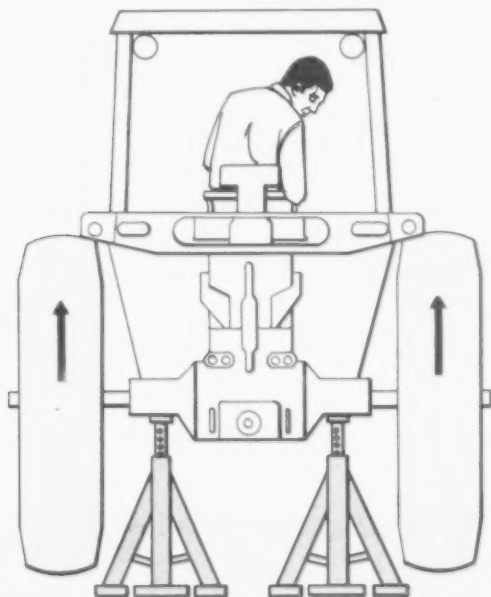


Fig. 39—Turning Shoe Brake Adjusting Screw

Adjusting Mechanical Band Brakes

To adjust band brakes:

1. Adjust the brake pedal free travel at either the pedal or the brake band, whichever is recommended in the operator's manual.

2. Tighten or loosen the adjusting mechanism until the recommended free travel is obtained.

3. Check the brakes for equal braking action while the machine is still off the ground. Follow the procedures described above for disk brakes, steps 5 through 11.

4. Lower machine to ground. Never rock the machine from its blocks.

The adjustments for mechanical brakes have been discussed earlier. The following discussion concerns hydraulic brakes.

Adjusting Hydraulic Brakes

Three procedures are required to adjust hydraulic (trapped oil) brakes:

- *Bleeding Brakes*
- *Adjusting Push Rods*
- *Adjusting Brake Mechanism*

If brake pedal action feels soft or spongy, bleed the brakes using the following steps. The machine should not be raised off the ground.

Bleed the brakes using the following steps. The machine should not be raised off the ground.

BLEEDING HYDRAULIC BRAKES

To bleed brakes:

1. Locate the brake master cylinder (Fig. 40) and the slave cylinder (Fig. 41). The master cylinder is usually near the brake pedals and the slave cylinders are attached near each brake housing.

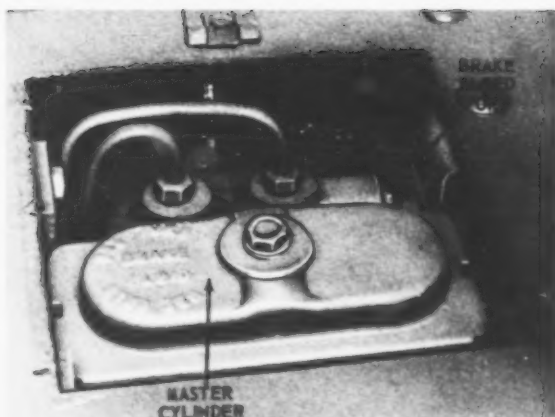


Fig. 40—Brake Master Cylinder Bleed Port

2. Clean dirt from the cylinders and especially the bleed screws.
3. Check the fluid level in the master cylinder. If necessary, fill the reservoir with the recommended fluid.
4. Have someone sit in the operator's seat to operate the brake pedals. Describe what you are about to do so that you work together.
5. If the master cylinder has a bleed valve, bleed it first (Fig. 41).
6. Have your assistant slowly depress the brake pedal for the right brake while you crack the bleed valve. Allow the fluid to escape slowly. If air is in the cylinder, bubbles will be released as you do this.
7. Close the bleed valve before the brake pedal is released. The pedal must be released slowly to avoid churning the fluid and creating more air pockets.
8. Repeat this procedure until no bubbles appear at the bleed valve. Also, repeat these steps for the other cylinder.

Check the master cylinder to be sure that sufficient fluid still remains in the reservoir. Fill again if necessary.

9. Now bleed the nearest slave cylinder in the same manner. Repeat for the other slave cylinder. Check the fluid level in the reservoir and fill if necessary.

10. Check the pedal action for a soft or spongy feel. If the pedal does not have a firm feel, there is still air in the lines and cylinders. Repeat the bleeding procedures.

11. Refill the reservoir to the proper level. Replace reservoir cover.

ADJUSTING HYDRAULIC BRAKE PUSH RODS

To adjust the push rods:

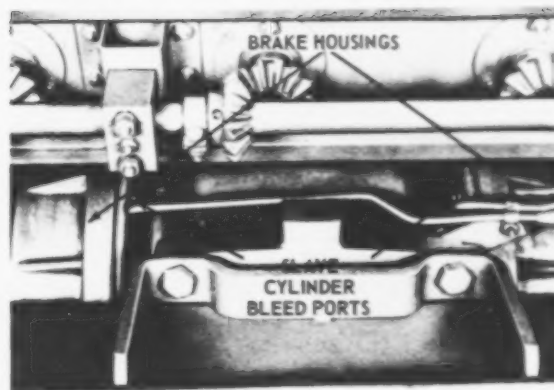


Fig. 41—Brake Slave Cylinder Bleed Ports

1. Loosen the lock nuts on the push rods of the master cylinder (Fig. 42).
2. Adjust the push rods until proper pedal free travel is obtained or until the push rods contact the cylinder pistons. Each push rod must be adjusted so that the pedals are equal when the brakes are applied.
3. If the operator's manual recommends this adjustment for the slave cylinders, adjust them also.
4. Check the brakes for equal braking action. Do this by jacking up the machine so that the drive wheels are off the ground (see Fig. 38). Be sure to block the other wheels to prevent the machine from moving. Support the machine securely with stands or blocks.

CAUTION: Do not use concrete blocks which may break or crumble and permit the machine to fall.

Fig. 42—Adjust The Push Rods



ADJUSTING HYDRAULIC BRAKE MECHANISM

To adjust the brake bands, disks or shoes, follow the procedures described earlier for disk, band or shoe brakes, steps 5 through 11. If the brakes don't slow at the same rate, adjust the push rods or bleed the brakes again. When one side of the hydraulic system still contains air, it will not apply as much pressure to the brakes as the other side.

TIRES



Fig. 43—Big Tires Are Expensive—Take Care Of Them

Tire replacement can cost thousands of dollars for larger machines. If tires are not properly inflated or are abused, their life can be shortened greatly. For example, underinflation can reduce tire life by up to one-quarter. This alone could cost hundreds of dollars. Tire abuse such as spinning wheels can wear tires even faster.

Maintaining tires properly takes only a few minutes periodically. Here are the key maintenance items:

- **Tire Inflation**
- **Ballast**
- **Tire Failures**
- **Safety Tips**

Let's look at each one.

TIRE INFLATION

Proper inflation is vitally important to proper service life of the tire. Tires are designed to operate with a certain sidewall deflection or "bulge." Correct air pressure helps provide proper traction, flotation, support of loads, and prevents excessive flexing of the tire which could cause sidewall cracking. See Fig. 44 for typical tire construction.

Overinflation

Overinflation prevents full contact of the tire tread with the ground or road (left, Fig. 45). This subjects the center of the tread to excessive wear. Because the tire is more rigid, it is more liable to damage by striking curbs, rocks, and other objects which could cause breakage of the cord plies.

Underinflation

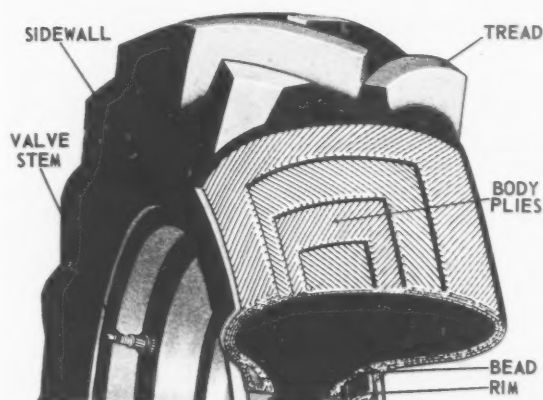
Underinflated tires (center, Fig. 45) flex excessively at every turn of the wheel, resulting in high internal heat and premature failure. Underinflation is indicated by excessive wear of the sides of the tread while the center is relatively unworn.

NOTE: Radial tractor tires, even when properly inflated, appear to "squat" or bulge more than properly inflated conventional tires. Always check pressure with a gauge. Don't rely on tire appearance.

Proper Inflation

Correctly inflated tires (right, Fig. 45) permit all of the tread to contact the ground, yet are not soft enough to flex excessively.

Fig. 44—Typical Tire Construction



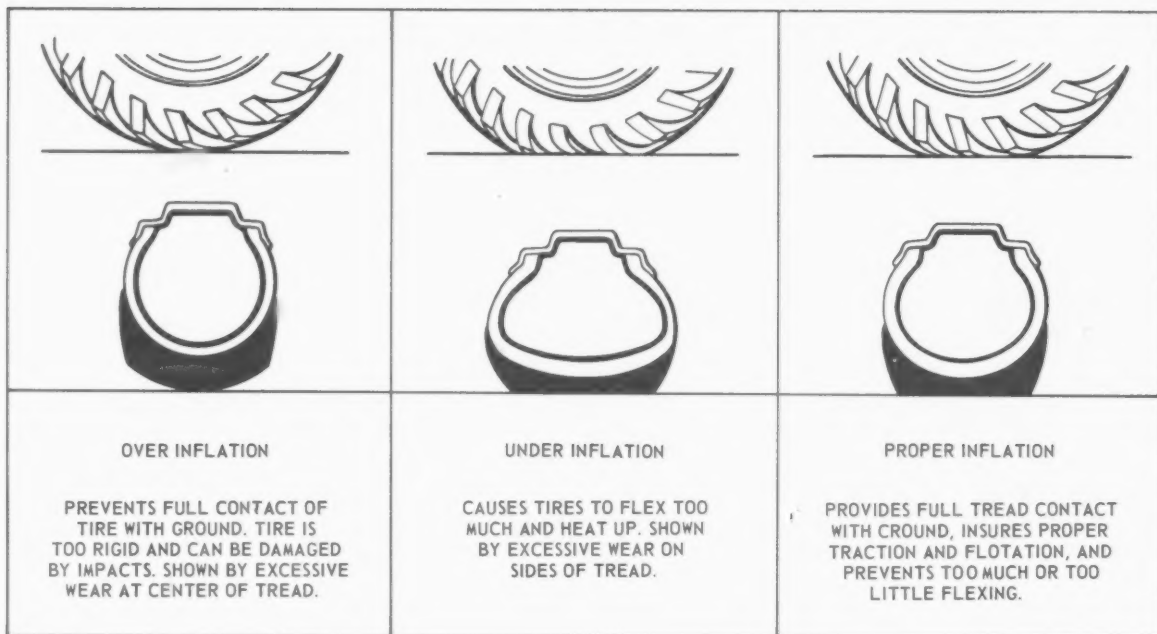


Fig. 45—Tire Inflation

Tire Pressure Gauge

Proper inflation must be maintained at all times through all seasons. This makes it important that an *accurate pressure gauge* be used when checking inflation pressures. Also remember that tires gain pressure in hot weather and lose pressure in cold weather.

Two types of pressure gauges are usually available—*high-pressure* and *low-pressure*—for either dry or liquid testing.

Always use the proper type gauge when checking pressure. Normally, high-pressure gauges are not satisfactory for checking low-pressure tires as the gauges are usually calibrated in five-pound increments while low-pressure gauges are calibrated in one-pound increments.

Most important is that the gauge be *accurate*. Accuracy can only be determined by checking the gauge against a gauge of known accuracy.



Fig. 46—Low-Pressure Tire Gauge

For this reason, keep one accurate gauge for the sole purpose of checking the accuracy of the gauge normally used. This is especially important with low-pressure gauges.

A low-pressure tire gauge is shown in Fig. 46.

Tire Inflation Rules

Here are four rules that must be observed for proper tire inflation:

1. *Always check and inflate tires when they are cold.* This is very important because tires become heated through use and the air expands thus the pressure increases.
2. *Never "bleed" air pressure from warm or hot tires.* This always results in the tire pressure being too low when its temperature becomes normal and often results in tire damage when put under load. Instead of bleeding air from hot tires, reduce the load, the speed, or both.
3. *If a tire becomes low while operating, adjust pressure the same as other tires of the same size on the machine.* Recheck the pressure after about 30 minutes of operation to be sure it is still correct.
4. *Always use a liquid-type pressure gauge when checking pressure in tires with liquid ballast.* Check pressure with the valve stem at the bottom. Always wash the gauge with clean water after checking the tires.

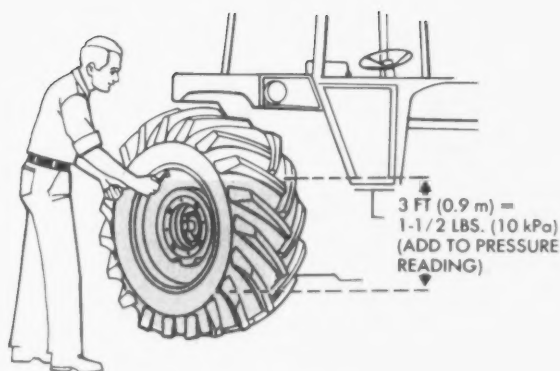


Fig. 47—Optional Method Of Checking Air Pressure With Valve Stem At Top

If it is impossible or undesirable to check the pressure with the valve stem at the bottom, locate the stem at the top (Fig. 47).

For actual pressure, add about $\frac{1}{2}$ psi (3.4 kPa) to the pressure gauge reading, as shown, for each foot the liquid is above the lower valve stem position.

Proper Amount Of Tire Inflation

Recommended tire inflation varies with size, ply, and load on tire (see tractor chart on next page). An average recommendation for a six-ply front tractor tire is 36 psi (250 kPa) (more with front-mounted equipment). An average six-ply rear tractor tire is 16 psi (110 kPa) (more with heavy ballast or rear-mounted equipment). Always follow your operator's manual for the exact tire pressure.

How To Inflate Tires

To check tire inflation:

1. If the tire contains ballast, be sure the valve stem is positioned correctly as described in the rules above, or use the method shown in Fig. 47.
2. Remove valve cap and check air pressure. Be sure to hold the gauge firmly against the valve stem to get a correct reading.
3. Check pressure again if you think a poor contact was made.
4. Add or release air as needed to obtain correct air pressure.

Do not exceed the maximum recommended air pressure. Some tire manufacturers recommend that you put a few more pounds in tires under the following conditions:

TIRE INFLATION

6-ply		
Front tires	Lowest	Highest
All 7.50 sizes	20 psi (140 kPa)	36 psi. (250 kPa)
6.50	20 (140)	44 (300)
5.50 and 6.00	20 (140)	48 (330)

4-ply		
Front tires	Lowest	Highest
All 7.50 sizes	20 psi (140 kPa)	24 psi. (165 kPa)
6.50	20 (140)	28 (195)
5.50 and 6.00	20 (140)	32 (220)
5.00	20 (140)	36 (250)
4.00	20 (140)	44 (300)

8 and 10-ply		
Rear tires	Lowest	Highest
18.4 8-ply	16 psi. (110 kPa)	20 psi. (140 kPa)
23.1 8-ply	16 (110)	16 (110)
23.1 10-ply	16 (110)	20 (140)
24.5 10-ply	16 (110)	18 (125)

6-ply		
Rear tires	Lowest	Highest
All 18.4	16 psi. (110 kPa)	16 psi. (110 kPa)
16.9	16 (110)	16 (110)
14.9	14 (95)	18 (125)
13.6	14 (95)	20 (140)
12.4	12 (80)	22 (150)
11.2	12 (80)	24 (165)

4-ply		
Rear tires	Lowest	Highest
All 13.6	14 psi. (95 kPa)	14 psi. (95 kPa)
12.4	12 (80)	14 (95)
11.2	12 (80)	16 (110)
9.5	12 (80)	18 (125)

a. If mounted equipment puts most of the weight on one side of the machine, put a few extra pounds of pressure in the tires on that side, but do not exceed maximum pressure ratings.

b. If the tractor is used for plowing with one set of wheels in the furrow, inflate the furrow tires a few extra pounds (usually about 4 psi [30 kPa]) to avoid excessive buckling of tires (see Fig. 48). Again, do not exceed maximum pressure.

c. If the machine is to be operated on a paved or hard road for several hours, inflate all tires to the *maximum* recommended pressure.

Now let's take a look at how tire ballast affects traction and available horsepower.

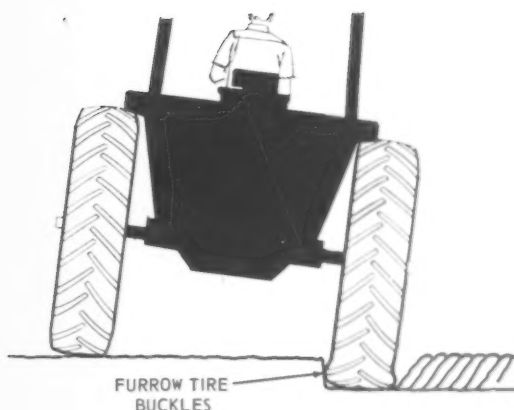


Fig. 48—Tire Tends To Buckle In Furrow

TIRE BALLAST

Tire ballast or weight can help give the most effective traction and power. The machine weight by itself may not be sufficient for full traction and drawbar pull. However, improper tire ballast can cause premature tire wear.

Farm tractors are the prime users of wheel ballast, so the discussion of ballast will refer mainly to them.

Tire Traction

Tire traction can be judged by looking at the tire tread pattern after pulling under load as shown in Fig. 49.

Too Much Weight

When *too much weight* is used, the tire tracks will be sharp and distinct in the soil (Fig. 49, top) and there will be no evidence of slippage.

This is bad, as the tires are literally geared to the ground and do not allow the flexibility of engine operation that is obtained when some slippage occurs.

Too Little Weight

When the tires have *too little weight* they lose traction. The tread marks are entirely wiped out (Fig. 49, center) and forward progress is slowed. Not only is less work done but the tires wear excessively. Reduced speed caused by excessive slippage can also cause over-application of chemical pesticides.

Proper Weight

When the tires have *proper weight*, a small amount of slippage occurs (Fig. 49, bottom). Usually, between 10 and 15 percent slippage is considered ideal in the field. When the tire is properly weighted, the soil between the cleats will be shifted but the tread pattern is still visible in the tire track as shown. Proper weighting allows the engine to perform at its best with maximum flexibility.



Fig. 49—Tire Traction Patterns

Adding Ballast To Tires

See your local service shop for adding ballast to tires. The tires can be filled about three-fourths full of liquid to add weight. Usually a mixture of water and calcium chloride solution is used to prevent freezing. Dealers

are equipped to mix and add solution to the tires. A special valve is needed to permit air to escape from the tire while the solution is being added.

If water is used instead of calcium chloride solution, it must be removed during winter in colder climates. Water also provides less weight per unit of volume than does calcium chloride solution.

Cast iron weights can also be attached to wheels for extra weight. Dual or triple tires are another way of improving traction and adding weight on larger tractors.

Remember that tire inflation should be higher when more ballast is added. See the operator's manual for recommended amounts under different operating conditions.

Dual And Triple Tires

Dual and triple tires are frequently added to improve traction and flotation of large tractors. Dual tires generally cost less than large single tires which would provide equal "footprint" or soil contact area. The extra weight of the added tires and wheels increases traction in adverse conditions. Extra tires also increase total load-carrying capacity (for more ballast, spray tanks, etc.). Total weight must not exceed load rating of the tires.

Tires used in dual or triple configurations must be matched in diameter and circumference to avoid uneven distribution of load. All drive tires on 4-wheel-drive machines should also be matched. Circumference of tractor drive tires, mounted and inflated, should not vary more than 1 1/2 inches (40 mm). Tires of uneven size can cause excessive tire slippage, axle breakage, difficult steering and other problems.

Adding dual or triple tires increases strain on axles and housings and is not recommended on some tractor models. Check with your tractor dealer or manufacturer if the operator's manual does not indicate acceptability of extra tires.

We have discussed basic tire maintenance. Now let's look at some tire failures which are caused by poor maintenance or abuse.

TIRE FAILURES

As we have said, tire failures may be caused by abuse, underinflation, overinflation, or just plain careless operation.

If tires aren't inflated properly, they are more subject to damage than under any other condition.

Inspect tires regularly for the following signs of damage. If the machine is operated as it should be, you probably won't find any tire damage as described here. However, the following will reveal what kind of damage is caused by abuse, underinflation or overinflation.

Tire Abuse

Tire abuse is any operation or lack of attention that will cause damage to tires.

Avoid driving over objects, such as large rocks, tree stumps or anything that may penetrate the tire or break the tire cords. An impact break is shown in Fig. 50.

Avoid spinning the tires. Engage the clutch slowly to prevent the tires from spinning. Use ballast and weights when pulling heavy loads to prevent spinning damage shown in Fig. 50.

Adjust the tire spacing to avoid stubble damage (Fig. 50) when operating in harvested corn or soybean fields.

Locate small cuts in the tire and bevel them to prevent stones and other small objects from embedding in the tire and causing leaks or broken cords (Fig. 50).

Check your machine for parts that may be rubbing or gouging the tires as they turn. Hitching or turning too short may cause this problem.

Underinflation

If your tires become underinflated, the sidewalls may buckle and break as shown in Fig. 51. This can occur when operating under heavy drawbar pull and when plowing with tires in the furrow. See the instructions on inflation described earlier.

Avoid operating on roads or other hard surfaces for long periods of time. If you must, inflate the tires to the *maximum* recommended pressure.

Overinflation

Avoid overinflating tires. Do not exceed the maximum pressure rating.

Breaks in the tire cord (Fig. 52) can occur much easier when striking an object with tires inflated above normal pressures.

Also, the center portion of the tire tread will become worn more rapidly than the outer portions.

SAFETY TIPS FOR TIRES

1. **FOR YOUR SAFETY**—Remember, an inflated tire can be very dangerous. Under pressure, for example, an 18-22.5 16 PR tire with 75 psi (515 kPa) pressure develops 103,789 Energy Foot-Pounds (140 717 J), and if it exploded, that energy could lift a 20,000 pound (9090 kg) tractor more than 5 feet (1.5 m) off the ground.

2. When inflating large tires, use a clip-on chuck and extension hose long enough to allow you to stand to one side and NOT in front of the tire assembly.

3. Before a jack is placed in position, block the tire and wheel on the *other* side of the machine. ALWAYS crib up with blocks or a stand just in case the jack should slip. NEVER use the jack alone.

4. Without proper tire repair equipment, tire service



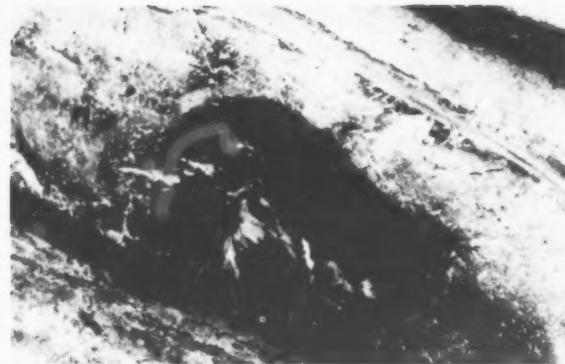
IMPACT BREAK



SPINNING WEAR



STUBBLE WEAR



EMBEDDED STONE

Fig. 50—Damage Caused By Tire Abuse

Fig. 51—Damage Caused By Underinflation

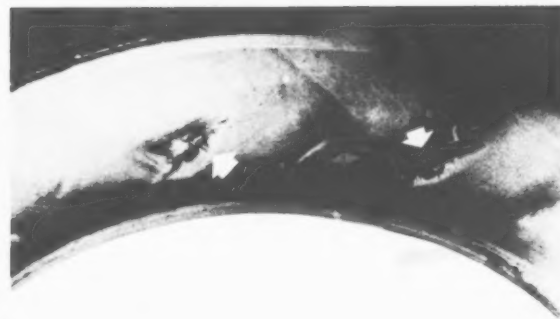
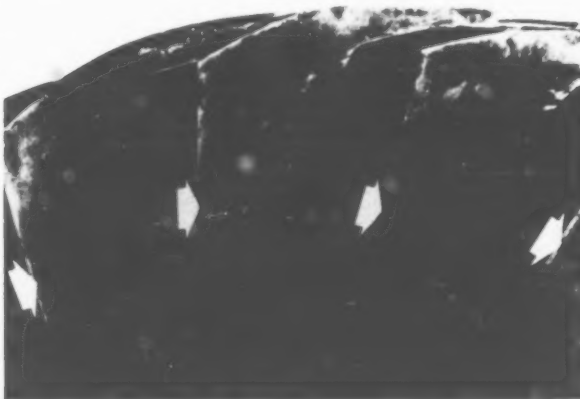
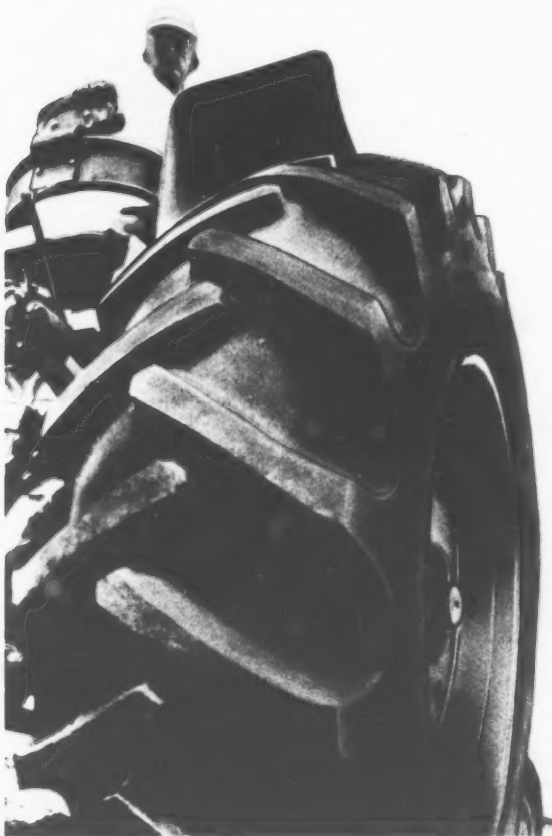




Fig. 52—Damage Caused By Overinflation

Fig. 53—Large Farm Tires Are Potential Safety Hazards



can be dangerous. Have tires serviced by a tire service shop that can do the job safer, easier and quicker.

GREASE FITTINGS

Many of the bearings on today's machines are sealed with lubricant for the life of the bearing. Some bearings still require periodic lubrication, but these are few in relation to the number of lubrication points used on machines several years ago.

It is an easy task to grease your machine when it requires it (Fig. 54). Your operator's manual recommends how each bearing or shaft should be lubricated and how much. Usually, pictures tell you exactly where each fitting is located so that you will have no trouble finding them. Fittings on axles and wheels were covered earlier in this chapter.

Some grease fittings require daily or 10 hours service, while others are serviced at 50 or even 250 hour intervals. Common fittings which need daily service are on steering, clutch and brake mechanisms, especially the mechanical types.

If you don't lubricate the bearings or shafts when required, these parts will wear out prematurely. Grease is not expensive and repair costs will be saved by keeping the machine properly lubricated.

Fig. 54—Lubricating At Grease Fittings (Wipe Fitting Clean First)



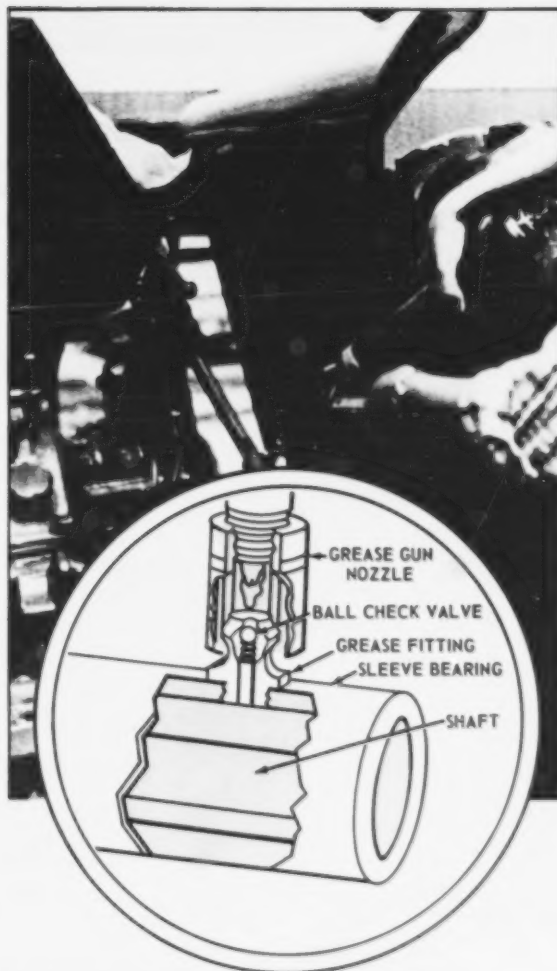


Fig. 55—How Common Grease Fittings Operate

OPERATION OF GREASE FITTINGS

When the grease gun is pushed down over the fitting, a seal is developed (Fig. 55). Pressure from the gun forces grease past a ball check valve in the head of the fitting. When the grease gun is removed, the check valve ball springs close to keep out dirt.

Some special fittings measure quantity or pressure, while others relieve excessive pressure, but these are not common on agricultural machines.

Grease Bank Systems

On some machines which have many fittings requiring regular lubrication, a central grease reservoir and pump

is used. A few strokes of the pump forces grease through small individual tubes to each bearing. The reservoir must be kept filled, and each bearing should be inspected regularly to be sure grease is reaching all bearings.

To provide easier access for lubrication of some hard-to-reach bearings on certain machines, small tubes are installed from the bearings to a central easily-reached location on the machine. Individual grease fittings on each tube are filled with grease in the conventional manner. These systems cost less than the central-reservoir type, and it is easier to tell if each bearing is being greased.

Grease tubes in each of these systems must be protected from moving machine parts to avoid tube damage and loss of lubrication.

TYPES OF GREASE

The development of *multi-purpose grease* has made it possible for the machine operator to use one grease for almost all fittings and hand-packed bearings.

Many operator's manuals recommend wheel bearing grease for packing wheel bearings, but multi-purpose grease is now considered to be satisfactory for some wheel bearing lubrication.

RULES FOR LUBRICATING BEARINGS

If you follow the rules listed below, you can expect bearings and shafts to provide maximum service.

1. Always lubricate parts with recommended lubricant. Multi-purpose grease is satisfactory for most applications.
2. Use clean lubricants. Be sure to store lubricants in clean, air-tight containers.
3. Always wipe off dirt and grease fittings before attaching grease gun. After lubricating, wipe off excessive grease.
4. Hold grease gun directly in line with fitting while pumping slowly. Remove gun by swinging through a 30° arc.
5. Do not lubricate bearings too often. Sometimes excessive grease can leak onto other parts and damage them—for example, drive belts, brake linings and clutch linings.
6. Never apply too much pressure or lubricant to bearings with seals. You may rupture the seal, allowing grease to escape and dirt and moisture to enter bearing.
7. In cold weather, grease at the end of the day while the bearings are warm—they will accept grease more readily.
8. Make it a habit to grease your machine at the recommended intervals.

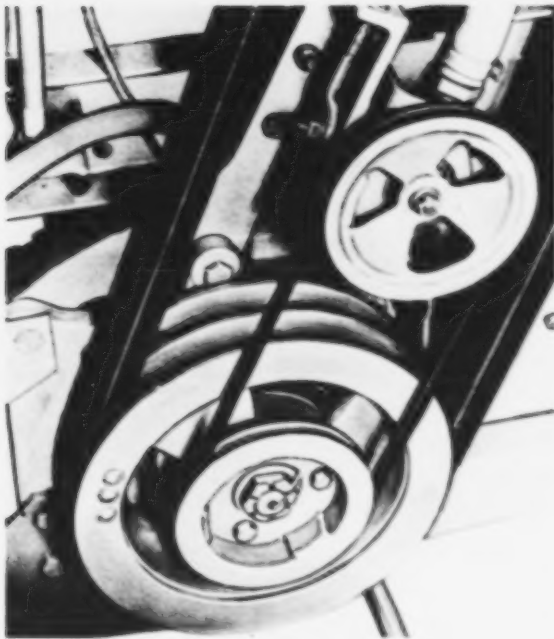


Fig. 56—V-Belt Drive Using Multiple Belts

BELT DRIVES

Almost every power-driven machine has either belts, chains, or both. These drive components must be maintained to keep them from wearing out prematurely. Belts can stretch and slip — chains wear and rust.

First, let's look at the maintenance for belts.

MAINTAINING V-BELTS

V-belts are the most common belt drive today, so our main story on maintenance will be for these drives.

We will discuss the following about belts:

- Tension
- Alignment
- Removal and Installation
- Wear

Tools And Materials Needed

1. Wrenches (inch or metric, as required)
2. Straight Edge
3. Ruler (inch or metric, as required)
4. Spring Scale

CAUTION: Never attempt to check or adjust belts while they are running. Always shut off the machine before servicing belts.

Belt Tension

Proper belt tension is one of the most important things in maintaining belts.

Fig. 57—Checking Belt Tension



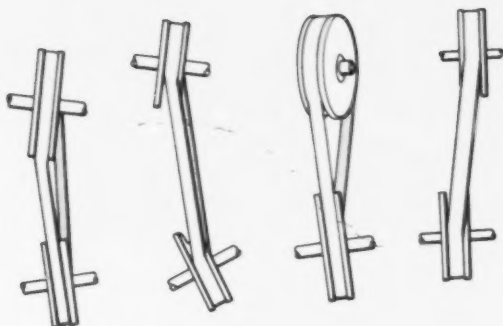


Fig. 58—Sheaves Not Aligned Can Damage The V-Belt

Too little tension will cause slippage or slip-and-grab, causing the belt to break. If the belt does not break, slip will cause excessive cover wear, burned spots, and overheating.

Too much tension will cause belt heating and excessive stretch as well as damage to drive components, such as sheaves and shafts. The extra tightness will also place heavier loads on the bearings.

Remember that V-belts should ride on the sides of standard sheaves, not on the bottom of the groove.

Watch the tension on a new belt *during the first 24 hours of operation*. This is when the initial seating and stretch occurs.

Check belt tension by deflecting the belt on one side with a spring scale. Measure the deflection at the recommended pounds (kg) pull. Your operator's manual will give you this specification.



Fig. 59—Check Alignment Of Belt Sheaves

Another method is to depress the belt halfway between the sheaves and use a ruler at right angles to a straight edge to measure deflection (Fig. 57, right).

Belt And Sheave Alignment

Check sheave alignment regularly. Be sure that the shafts are parallel and the belt aligns with each sheave.

Common types of misalignment (exaggerated) are shown in Fig. 58. All are caused by shafts not parallel or sheaves not aligned.

To check alignment, place a straight edge between the sides of the sheaves (Fig. 59). The straight edge must touch the sheaves at the four arrows. Rotate the sheaves and check at different points. If variation is noticed, either the sheaves or shafts are bent. Replace the defective parts.

Belt Removal and Installation

Before removing any drive belt, loosen the tightener. *Do not force the belt off the sheaves.*

When installing any drive belt, loosen the tightener. Never force the belt onto the sheaves (Fig. 60). You may break the strength cords in the belt and weaken the belt so that it fails rapidly.



Fig. 60—Never Force A V-Belt Onto A Sheave

Do not tighten the belt too much. Slight tension is always recommended on a V-belt.

On multiple belt drives, always replace all belts with a matched set of belts even though only one fails. Otherwise, the new belt may pull the whole load, because the older ones are probably stretched.

Troubleshooting V-Belt Wear

The examples shown in Fig. 61 will help you to recognize some of the signs of V-belt wear or damage.

The chart at right explains the causes of typical belt wear so that the problems can be corrected.

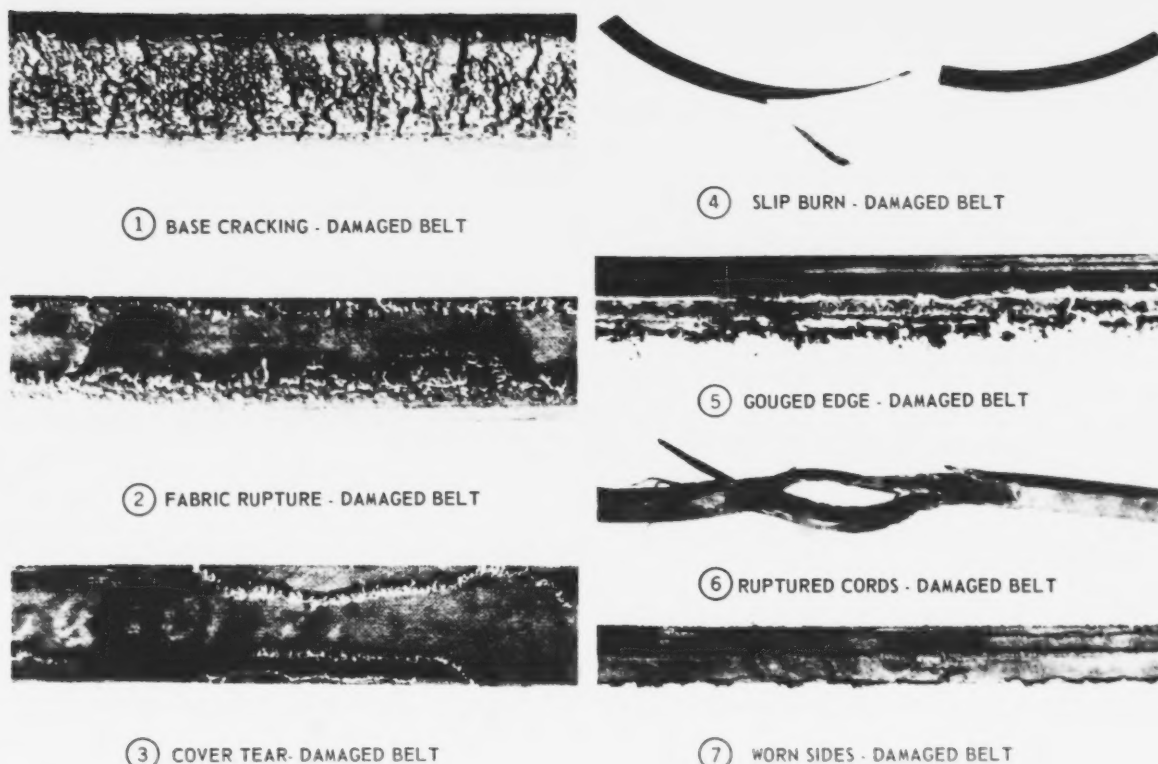


Fig. 61—Examples Of Wear On V-Belts

TROUBLESHOOTING V-BELT WEAR		
Symptom (Fig. 61)	Cause	Remedy
1. BASE CRACKING	Normal aging. Weather rotted inner fabric.	Replace belt.
2. FABRIC RUPTURE	Prying belt onto sheave. Worn sheaves. Belt too tight.	Loosen belt tighteners before installing belt. Do not tighten belt too much. Also, replace belt.
3. COVER TEAR	Belt coming into contact with some part on machine.	Find interference and eliminate it.
4. SLIP BURN	Belt operated too loose. When operated under load, it finally grabbed and snapped.	Tighten belt properly. Also, replace belt.
5. GOUGED EDGE	Damaged sheave or interference from some part on machine.	Check condition of sheaves and check for interference. Also, replace belt.
6. RUPTURED CORDS	Driven sheave locked and drive sheave burned area of belt because belt would not rotate with sheave.	Avoid overloading drive and lubricate bearings to prevent bearing seizure. Also, replace belt.
7. WORN SIDES	Long operation without enough tension.	Check belt tension regularly and keep it properly tightened. Also, replace belt.

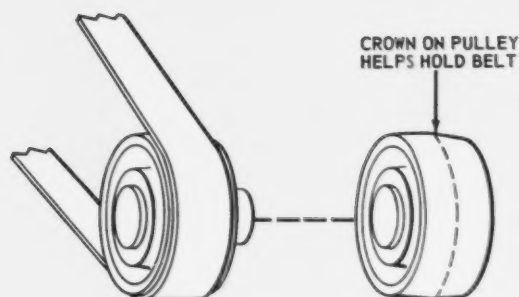


Fig. 62—A Crown Helps Keep Flat Belt On Pulley

MAINTAINING FLAT BELTS

Many of the maintenance tips for V-belts also apply to flat belts.

Here are some of the rules:

1. Some flat belts, usually leather or canvas, may require belt dressings to prevent slippage and deterioration.
2. Flat belts normally need more tension than V-belts.
3. Pulley alignment is even more important with flat belts than for V-belts because flat belts can run off the pulley easier.
4. To install flat belts, move the power unit forward, place the belt on the pulleys, and back up carefully to tighten the belt. Start the belt slowly to make sure it is running straight before increasing the speed.
5. *Never* force a belt off a moving pulley.

CHAIN DRIVES

Chain drives are used on some machines. They can eliminate the slippage that belt drives may give in some applications. Where timing is important, chains are often a must.

Because chains are under much stress, they must be maintained properly or they will fail in a short time.

Chain drives have one or more sprockets and an endless chain (Fig. 63).

One sprocket is normally mounted on a power shaft and is the driving sprocket for the complete drive. The second sprocket is driven in turn by the driving sprocket as shown.

A third sprocket may be used to adjust tension on the slack side of the chain.

We will discuss the following about chains:

- Tension
- Lubrication
- Alignment
- Removal And Installation
- Wear
- Cleaning

TOOLS AND MATERIALS NEEDED

1. Wrenches (inch or metric, as required)
2. Straight Edge
3. Lubricating Oil
4. Solvent
5. Container of Oil to Soak Chain
6. Chain Detaching Tool

CHAIN TENSION

Chain tension—or “slack”—is vital to the proper operation of chain drives. Unlike belts, chains require no initial tension and should *not* be tightened around the sprockets. Properly adjusted chain drives should permit slight flexing by hand in the slack strand of about two percent of the center distance (Fig. 64).

Too much tension causes the working parts to carry a much heavier load than is necessary and work much harder without delivering any more power. This

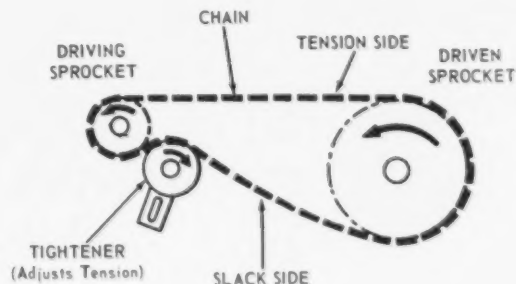


Fig. 63—Parts Of A Chain Drive

causes rapid chain wear because of more pressures in the joints. In addition, shaft bearings are overloaded.

Too little tension is also harmful. On long centers, particularly, too much slack will cause vibration and

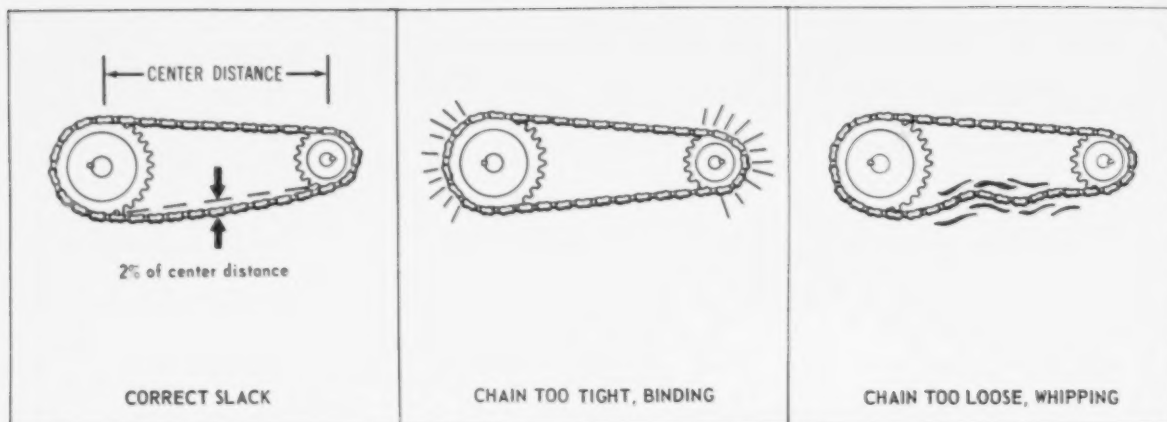


Fig. 64—Chain Slack (Tension)

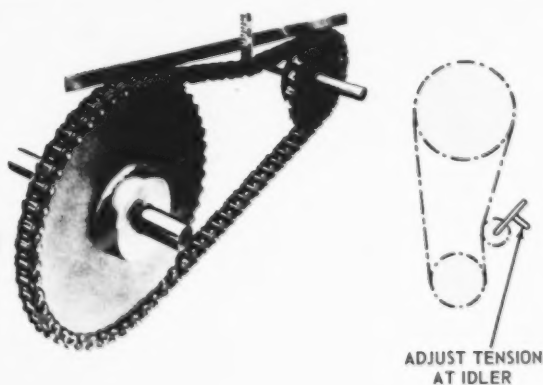
chain whipping, reducing the life of the chain. On long centers, the slack strand should be supported or taken up by idler sprockets or guides.

Adjusting Chain Tension

To adjust chain tension:

1. For horizontal and inclined drives, the chain sag should be about $\frac{1}{4}$ inch per foot (2 mm per m) between shaft centers (with one side of chain taut).
2. Vertical drives and those subject to shock loading or reversal of rotation should be adjusted so that both spans of chain are almost taut.
3. For drives on fixed centers, chain tension is usually controlled by an adjustable chain tightener, either an idler sprocket or a shoe.
4. To determine the amount of sag, pull one side of the chain taut, allowing all the excess chain to accumulate in the opposite span.

Fig. 65—Adjusting Chains



5. Place a straight edge over the slack span and pull the chain down at the center (Fig. 65). Measure the amount of sag from the top of the chain to the underside of the straight edge.

6. If necessary, adjust the shaft centers or the tightener to provide the recommended amount of sag for proper chain slack.

CAUTION: Never attempt to adjust chains while they are operating. Always shut off the machine before servicing chain.

CHAIN LUBRICATION

Lubrication of chains is perhaps the most important factor in long service life. Running dry, exposed chains have been known to wear out in less than 200 hours. Manual lubrication can extend wear life three to ten times over life with no lubrication.

Dripping oil on the outside of the chain may not be enough. Oil must reach the vital bearing surfaces pointed out in Fig. 66, top. To do this, oil must penetrate the gap between the inside and outside plates of roller chains. This can be helped by oiling the chain while it is warm and then running it for a short time. Always oil the chain at quitting time each day, and let it set overnight.

Chains which collect dirt and dust should still be oiled regularly. A "paste" of oil and dirt still wears less than dry dirt packed into the chain joints. Lubrication also helps prevent rust.

NOTE: For abrasive soil or sandy conditions, some manufacturers may not recommend lubrication of chains. However, this is the exception, not the rule.

CHAIN AND SPROCKET ALIGNMENT

Proper alignment of sprockets and shafts is necessary for maximum wear life. Rapid wear will result from misalignment due to rubbing of chain parts

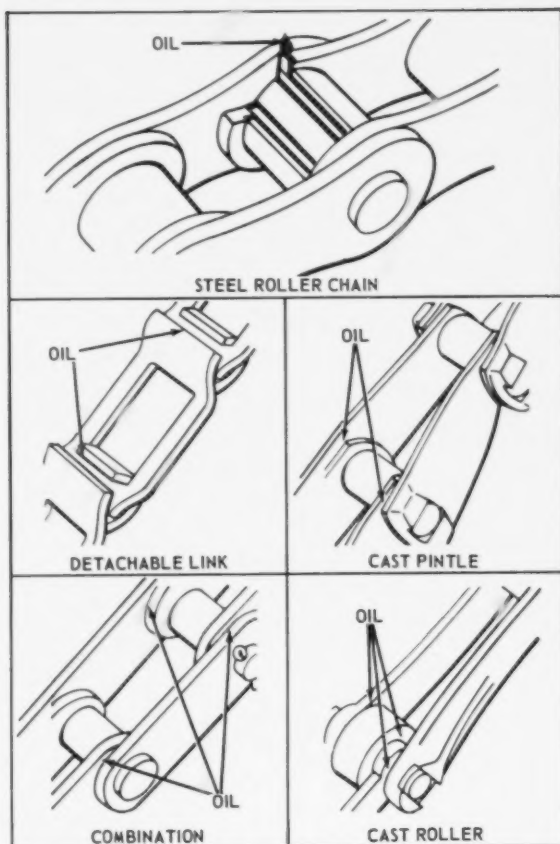


Fig. 66—Lubrication Points on Chains

against sides of sprocket teeth and excessive friction wear in the joints caused by whipping and twisting of chains.

Align the sprockets axially on the shafts, using a straight edge (Fig. 67). Take care to apply the straight edge to a finished surface on the side of the sprocket. For long center distances, a stretched wire or cord can be used instead of a straight edge.

CHAIN INSTALLATION

To couple the ends of a chain:

1. Loosen the tighteners to provide sufficient "working slack."
2. Bring the ends together over one sprocket, using the teeth to hold the chain.
3. Insert pin or pin link to couple chain into an endless strand (Fig. 68).
4. Adjust tighteners to provide proper tension for operation.

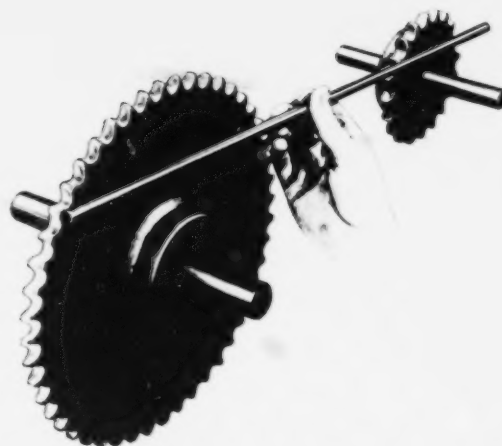


Fig. 67—Aligning Sprockets Using A Straight Edge

The above method is especially useful for coupling drive chains.

When it is necessary to couple long, heavy chain in the span between sprockets, draw the ends together with a block and tackle or other device. Then follow steps 3 and 4 above.

Keep chain straight when coupling. A link coupled when the chain is crooked may cause the chain to twist in operation.

Fig. 68—Installing Roller Chain



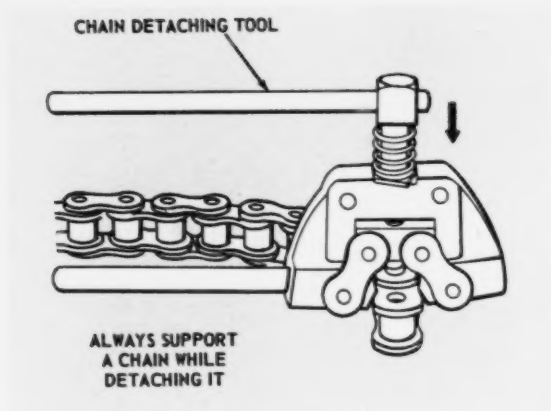


Fig. 69—Chain Detaching Tools For Roller Chain

To provide a solid back-up for the chain, assemble it in a straight line on the floor or a table. Then feed the chain onto its drive.

CAUTION: Keep all chain guards and shields in place during operation.

Chain Removal

The chain detacher is a convenient bench tool for uncoupling roller chain (Fig. 69). It is designed to prevent damage to the chain during disassembly.

The best rule when detaching any chain is: *Support the chain while detaching it.* This will avoid bending of links.

CHAIN AND SPROCKET WEAR

As chains wear and stretch, they do not mate properly with their sprocket teeth. Badly worn roller chains

Fig. 70—Comparing New And Worn Roller Chains

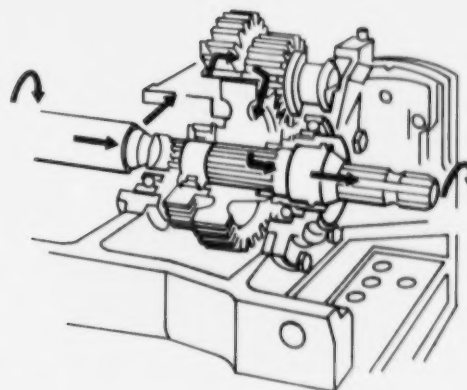
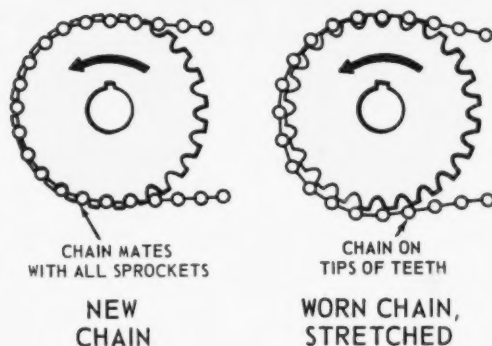


Fig. 71—Gear Drive

ride so far out of the tooth pockets that they may be off the working faces (Fig. 70, right).

As a rule, when a chain is worn until it has lengthened by three percent or more, it should be replaced.

When new chains are installed on excessively worn sprockets, the new chain will wear rapidly. Sprockets should be replaced or reversed if possible when the teeth develop a *hooked* appearance.

CLEANING CHAINS

Periodic cleaning of chains is good economy under even the best operating conditions. Follow these steps:

1. Remove chain from sprockets.
2. Wash chain in solvent.
3. Drain solvent and soak chain in oil.
4. Hang chain to drain off excess lubricant.
5. Install chain.

GEAR DRIVES

Gears are the most common way to transmit power for heavier loads. With gears in mesh, all slippage is gone. Even the linkage of the chain is eliminated giving more power potential.

OPERATION

Chapter 7 on "Power Trains" covers the basic gear types and their uses. Refer to that chapter for the basics of gear drive operation.

This discussion will cover only the small open gear drives which require special lubrication or adjustment.

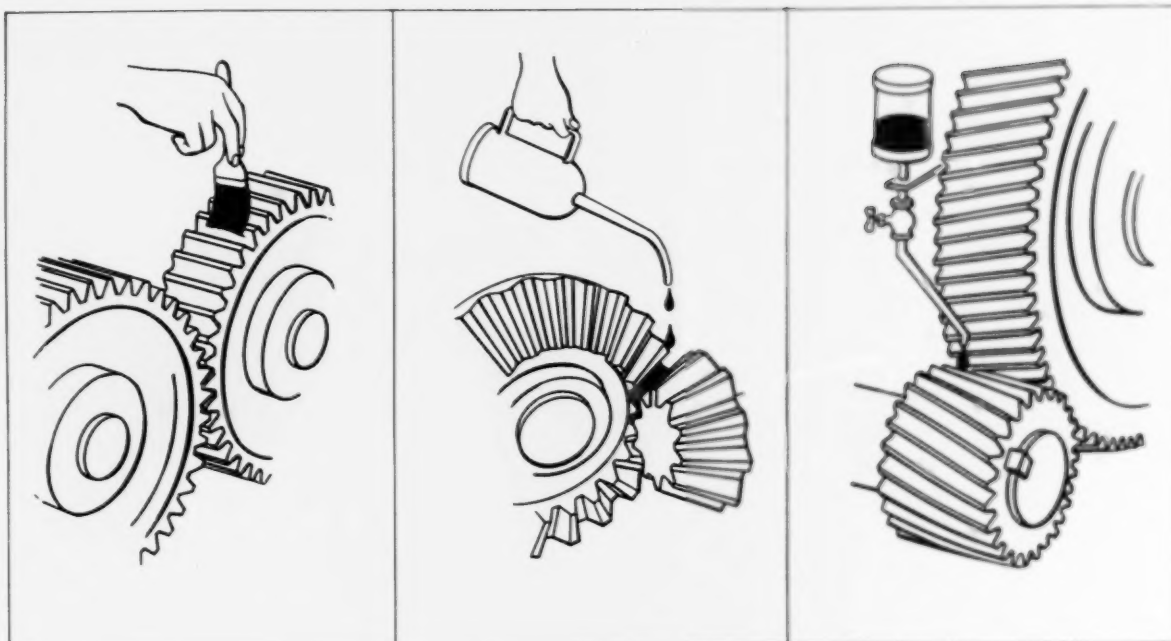


Fig. 72—Three Ways Of Lubricating Open Gears

LUBRICATION OF GEARS

Gear lubricants range from simple mineral oils to complex formulas containing many ingredients.

For the type of oil to use, consult your machine operator's manual.

Common gear lubricants are:

SPUR GEARS—may use a good grade of petroleum oil—but not always.

BEVEL GEARS—may use an extreme-pressure (E.P.) lubricant.

WORM GEARS—may use an SCL lubricant, which offers even greater lubricant qualities.

Methods Of Lubricating Gears

Enclosed Gears (Chapter 7) are usually lubricated by the gears moving through a sump of oil and may have additional run-off troughs to lubricate the upper gears.

Open gears can be lubricated by:

1. Splash pan which the gears run through.
2. Hand lubrication by brushing or squirting with oil can (Fig. 72).
3. Automatic lubrication by a drip oiler.

Check the operator's manual for the proper intervals and types of lubricant.

ADJUSTING THE GEAR DRIVE

When a gear drive is operated, reaction loads from gears, etc. are transmitted to the bearings and the various parts deflect.

For this reason, the gear drive may periodically require adjustment for the proper fit between parts.

Three kinds of adjustments are used:

- **Backlash**—clearance or "play" between gears in mesh
- **Endplay**—end-to-end movement in a gear shaft due to bearing clearances
- **Preload**—a load within the bearings set up by adjustment

These adjustments should only be made following instructions in the machine service manual and using proper tools and equipment.

Backlash In Gears

Too much backlash in gear trains is the result of: 1) improper mesh between gears or 2) lack of support in bearings.

The result of too much backlash can be broken gear teeth or bouncing of gears under impact forces.

Backlash is often adjusted to a specified reading on assembled gears (Fig. 73).

The dial indicator is mounted so that it registers the full rotary movement of the ring gear shown. To adjust the backlash reading, shims are often used.

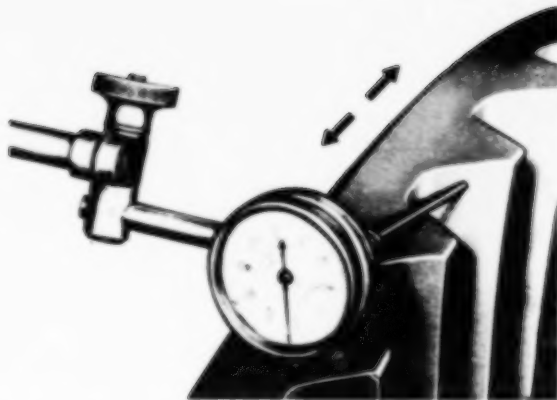


Fig. 73—Checking Backlash On Gear

Endplay in Gears And Shafts

Too much endplay is caused by lack of bearing support for the thrust produced by the gears rotating.

Preloading is often used to take up the slack and load the bearings.

To check endplay (Fig. 74), a dial indicator is mounted against the side of a gear or the end of a shaft. The gear or shaft is then pried in both directions and the readings noted. The difference between the two readings is the endplay.

Fig. 75—Lighting On A Combine

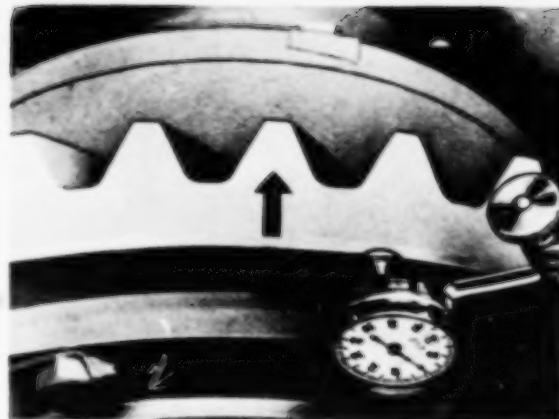


Fig. 74—Checking Endplay On Gears And Shafts

Shims or adjusting nuts are widely used to adjust endplay.

Preloading Of Gear Drives

If the loads are heavy or the thrust too great, gear trains are often preloaded to reduce the deflection of parts. This preload must fit the design of the bearings and the strength of the parts.

If bearings are preloaded too tight, they will heat up and fail. If they are set too loose, the supporting parts will deflect too much, causing them to wear rapidly.

Gear drives are preloaded by shims, thrust washers, adjusting nuts, or by double-race bearings.





Fig. 76—Lighting On A Tractor

LIGHTING AND ELECTRICAL ACCESSORIES

This section covers some of the extra equipment which completes the electrical system on machines.

The basic electrical system was covered in Chapter 6 on batteries and charging, starting, and ignition circuits.

Now let's fill in the remainder of the system with the lighting and other electrical accessories:

- Lighting Circuits
- Circuit Breakers and Fuses
- Wiring Harnesses
- Gauges
- Meters
- Switches
- Electric Motors
- Cigarette Lighters
- Stereo Tape Players

Let's take a closer look at each of these accessories.

LIGHTING CIRCUITS

Lights are used on most modern agricultural ma-

chines. They are required by state or local governments for night driving or towing in most areas. To avoid trouble, know your local regulations.

On modern machines, the lights are often two or four headlights and one taillight (Fig. 76). This usually requires a 12-volt system.

In addition, a flashing warning lamp or lamps is required in most states. This lamp warns other traffic that a slow-moving vehicle is on the road. A slow-moving vehicle (SMV) emblem is also required in many states (Fig. 76).

On many agricultural implements, special lighting is used for night work in the field. On a self-propelled combine, for example, a special flood lamp is used to light up the area where the grain is being cut and fed into the combine (Fig. 75). Another flood lamp shows the operator when the grain tank is full of grain.

Layout Of The Lighting Circuit

The lighting circuit is normally a part of the complete electrical system. It operates on power from the battery with help from the charging circuit.

The parts of a typical lighting circuit are shown in Fig. 77. They are the various *lamps* which are operated by a *light switch*. The switch is connected to the battery or charging circuit by the *wiring harness*. Other accessories shown are an electrical outlet socket and indicator lamps. The circuit is protected from a current overload by the *circuit breakers* and *fuses*.

On most machines, the starter switch must be turned on before the lights can be operated by light switch.

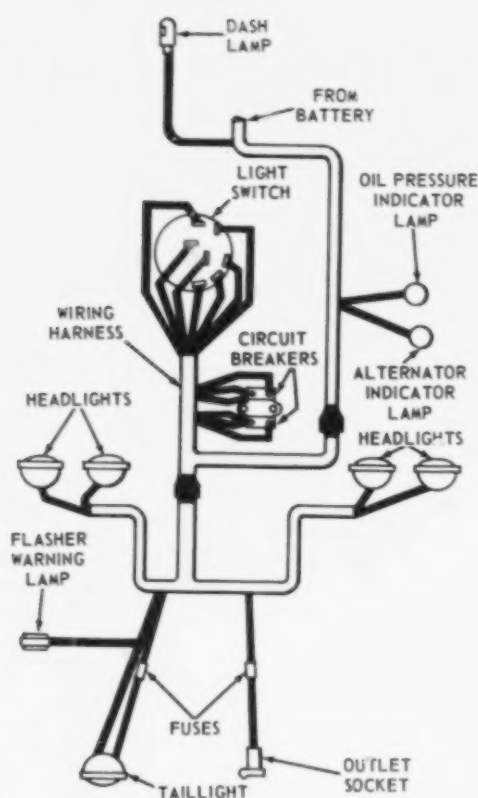


Fig. 77—Layout Of A Typical Lighting Circuit

Also, some machines have indicator lamps which light up when the starter switch is turned on and then go out when the engine is running, showing that the alternator, oil pressure, etc., are normal.

On machines with two or four batteries, a "split-load" lighting circuit is sometimes used. This divides the load equally between both batteries, when the lights are turned on.

Lamps

Lamps used for lighting of modern machines are:

- Sealed-beam units (for headlights and flood lamps)
- Light bulbs (for other lights)

Sealed-Beam Units

Headlights and flood lamps are normally sealed-beam units.

The headlights throw out a high-intensity beam and should always be dimmed when approaching a vehicle at night.

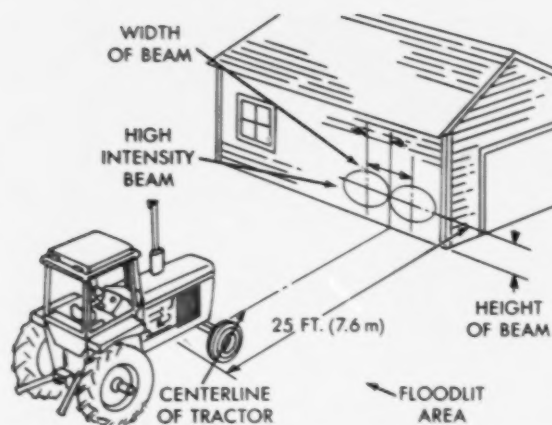


Fig. 78—Adjusting Headlights

Adjusting Headlights

When headlights are used on public roads, be sure they are adjusted so that the glare of the lights will not shine into the eyes of approaching drivers.

Adjusting the headlights on a typical tractor is shown in Fig. 78. This procedure can be used for other machines also.

Position the machine, as shown, on level ground squarely facing a wall 25 feet (7.5 m) away.

Turn the headlights on "bright" and check the height of the beams on the wall. The centers of the light beams should be 1 to 4 feet (0.3 to 1.2 m) high, depending upon the height of the headlights. Keep the intense part of the beams at least 5 inches (15 cm) below the center of the light from which it comes.

The headlights should also be parallel to the tractor centerline. Look down the center of the machine to see if the centers of the beams are at equal distances from the centerline (about four feet [1.2 m] apart or two feet [0.6 m] off center on most tractors).

On machines with dual headlights, also check the outer flood lamps on "dim" to see that they shine downward and outward to illuminate the desired area as shown in Fig. 78.

To adjust the lights, loosen the lamp mounting bracket and rotate them as desired. Then retighten the mounting bracket. *Remember: Only the lamp mounting bracket is adjustable—not the sealed-beam unit itself.*

On other machines with headlights mounted higher than those on a tractor, always adjust the lamps downward far enough to avoid glare to oncoming traffic.

Light Bulbs

Miscellaneous lights such as taillights, dash lamps,

and indicator lamps are normally equipped with single- or double-contact bulbs.

When replacing bulbs, use the same style and part number as the old one. Otherwise, the system can be damaged or the bulb may burn out rapidly.

Special light bulbs for special lighting effects may be required for some taillights, flasher lamps, or indicator lamps.

Indicator lamps are often used in place of gauges for generator, oil pressure, and temperature checks.

If the indicator lamp lights up or glows while the engine is running this shows a failure in the system being monitored. For example, an oil pressure light may glow when the engine is low on oil.

When an indicator lamp comes on, be sure to stop the engine at once and check out the possible causes. But also remember that a burned-out indicator lamp never lights up, even while the engine is being ruined!

Failures of Lamps

Failure of lamps may be caused by a defective unit, a broken wire, a disconnected wire, a corroded connection, a switch failure or an open circuit breaker.

To check a light bulb, visual inspection is best. A good bulb will be clear while a burned-out bulb may be dark. Where the bulb glass is not dark, the filament wire will be visible. If it is broken, the bulb is defective.

To check a lighting circuit, test the faulty part for voltage drop. If you don't have a voltmeter, take the machine to a service shop for testing.

If the voltage is correct but the lamp is dim, look for a poor wiring connection between the lamp and the main wiring harness. Also check for a poor ground at the lamp mounting. Remember that the frame of the machine serves as the ground and good contact must be made to complete the circuit.

Fig. 79—Flashing Lamp

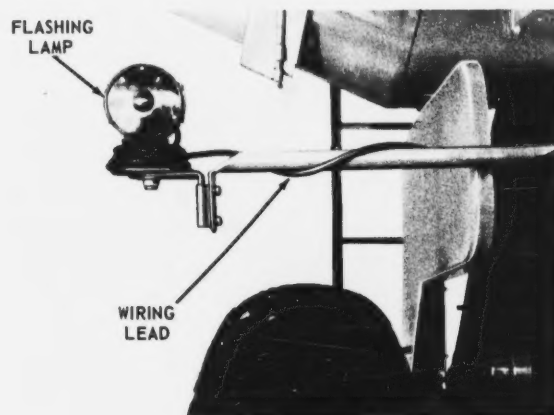


Fig. 80—Circuit Breakers For A Lighting Circuit

If there is no voltage across the lamp, look for a broken wire, poor contact in the light switch, or a disconnected wiring connector. Replace or repair any defective parts.

If the lights all go out suddenly, check for a tripped circuit breaker or a blown fuse. For details, see "Circuit Breakers" and "Fuses" later in this section.

Flashing Lamps

When a flashing warning lamp (Fig. 79) is prohibited by local regulations, disconnect the flasher unit and the short wire connected to the flasher. (See the operator's manual.) If you want to burn the warning lamp continually, connect the wire from the lamp directly into the lighting circuit wiring harness.

CIRCUIT BREAKERS

A circuit breaker (Fig. 80) protects an electrical circuit from current overload. The breaker acts as a switch and opens when the current passing through the circuit exceeds the rated level. The breaker may close automatically, after the switch is shut off for a short period. Some breakers have to be closed manually. Both automatic and manual reset circuit breakers are used in electrical systems.

In general, circuit breakers are used when heavy loads may be instantly placed on the circuit.

To check for a defective circuit breaker, use an ohm-

meter or a voltmeter. If an ohmmeter is used, a good circuit breaker will show zero resistance.

A defective breaker will show full resistance. If a voltmeter is used, and the circuit breaker is defective, the battery side will show voltage and the load side will not.

Again, if you don't have these instruments, take the machine to a service shop for testing.

Some circuit breakers are equipped with a reset opening. When the breaker trips, it may be reset by inserting a small wire in the opening and pushing against the spring tension (Fig. 81).

FUSES

Fuses protect an electrical circuit from current overload. When too much current passes through the circuit, the fuse blows, breaking the flow of current and preventing damage to the circuit.

A fuse consists of a fine wire or thin metal strip enclosed in glass or fire-resistant material. Most fuses used for modern agricultural and industrial equipment are small replaceable types. They have a contact on each end and are held in place in a fuseholder or panel (Fig. 82). The holder is usually a two-piece tube which can be easily separated for installing or replacing fuses. The fuse panel is a plastic or fiber board which contains many fuses. The panel keeps the fuses in one place and aids in fuse replacement.

Blown fuses are usually caused by:

1. A short circuit in the electrical circuit caused by defective wiring or a defective component (lights, motor, etc.).
2. An overload in the circuit caused by a surge of electricity passing through the circuit.
3. Poor contacts in the electrical circuit or the components.

Fig. 81—Resetting A Circuit Breaker

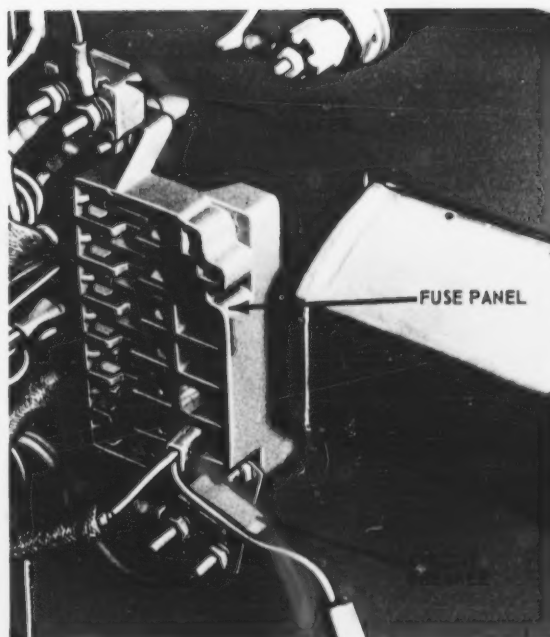


Fig. 82—Fuse Panel

4. Overheating in the circuit caused by overloads or poor contacts.
5. Use of incorrect size fuses in the circuit.
6. Fuse located too near a hot area such as an engine or a heater.
7. Vibrations near the fuse, causing the contacts to come loose.

Types of Fuses

Two types of fuses are widely used in machine electrical circuits:

- *Quick-blowing fuses*
- *Slow-blowing fuses*

A **QUICK-BLOWING** fuse blows instantly whenever a too-heavy load occurs.

A **SLOW-BLOWING** fuse will allow an overload for a short period before it blows.

Finding Cause Of Blown Fuse

By looking at a blown fuse, you can often tell what failure in the circuit caused it to blow.

Refer to Fig. 83 for a general check for causes of blown-out fuses—whether from overload or from short circuit.

QUICK-BLOWING FUSES:

If an **overload**—glass case will be clear because fuse link overheats and simply melts away.

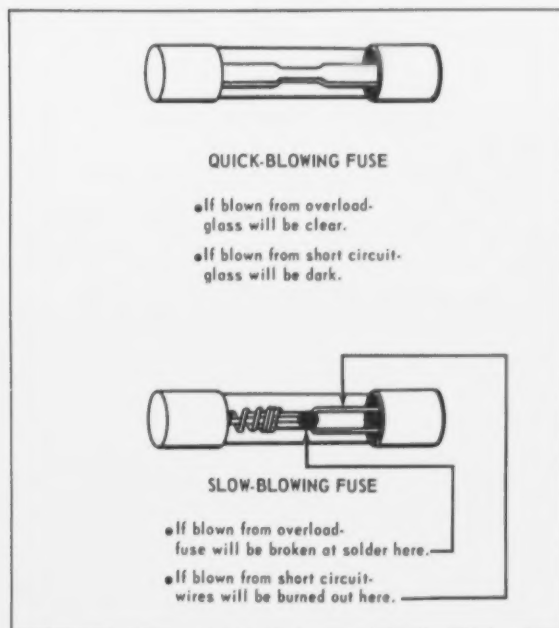


Fig. 83—Determining The Cause Of A Blown Fuse

If a *short circuit*—glass will be dark, stained by the fuse link which suddenly “burns up.”

SLOW-BLOWING FUSES:

If an *overload*—fuse link will break at solder, which has melted.

If a *short circuit*—fuse link will break at small wires because of sudden heat.

Remember that a fuse is meant to protect against overloads. It will also protect against short circuits, but these are abnormal and should be repaired at once.

If a quick-blowing fuse tends to blow out frequently due to small overloads, replace it with a slow-blowing type of the same size.

If the fuse still keeps on blowing, the circuit is overloaded and is not meant to handle the loads being placed on it.

Always replace a blown fuse with one of the same size.

Never use a fuse with a higher amperage rating as it may result in serious damage to the circuit it protects.

Fuses And Circuit Breakers—Where Used

Fuses are cheaper but not reusable. So they are used mainly in circuits where “blow outs” from heavy loads are not common.

Circuit breakers are more expensive but can be reset without replacement. So they are used in heavy-duty circuits where sudden heavy loads are expected—or where safety is a factor.

WIRING HARNESSES

A wiring harness is the trunk and branches which feed the electrical circuit. Wiring leads from one part of the circuit enter the trunk or sheath, joining other wires, and then emerge at another point in the circuit (Fig. 84). The harness sheath is normally made of rubber, cloth, electrical tape, or plastic tubing.

Be careful when installing a wiring harness. The harness must not interfere with moving parts of the machine. Also make certain that the clips which hold the

Fig. 84—Wiring Harness

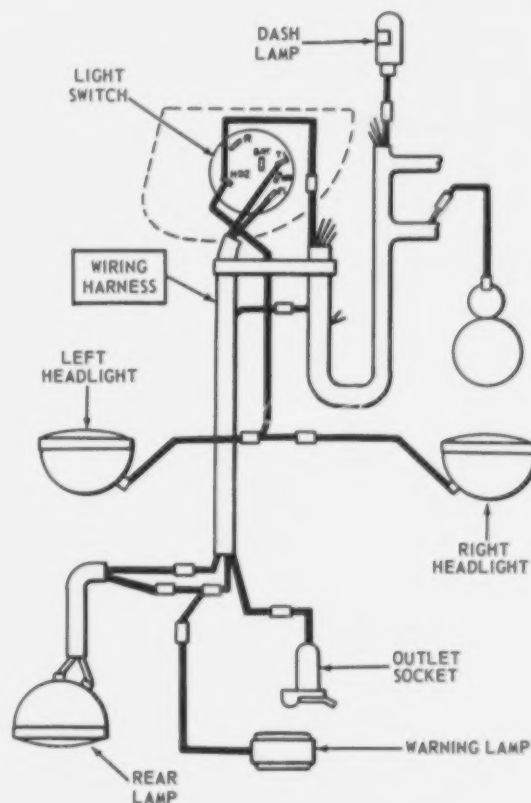




Fig. 85—Gauges And Meters On The Dash Of A Tractor

harness do not pinch through the harness and cut the wires. This can cause a short in the circuit.

Individual wires in a harness may be replaced by cutting off the defective wire at each end of the harness. Discard the removed ends of the wire. Run the new wire around the harness; do not try to thread the wire through the harness. Place the new wire in clips with the harness or attach to the harness with electrical tape.

The proper gauge or size of an electrical wire depends upon:

1. Total length of the wire in circuit.
2. Total amperes that the wire will carry.

But when replacing a defective wire in a circuit, remember:

Always use the same or heavier gauge of wire for replacement. Never use an undersized wire because it will not carry the required load and will overheat.

GAUGES

Gauges are used on modern machines to keep the operator informed on the various functions of the machine systems (Fig. 85).

Examples of these gauges are: fuel gauge, water temperature gauge, and oil pressure gauge.

The fuel gauge is controlled by a sensing unit located in the fuel tank and the water temperature gauge and oil pressure gauge are controlled by sensing units located in the engine radiator and cylinder block.

The sensing units are all variable resistance types and operate the gauges as follows:

The higher the water temperature, oil pressure, or level of fuel, the lower (or higher) the resistance in the sensing unit. This change in resistance causes

more (or less) current to pass through the connecting wire to the gauge coil, which in turn causes a new reading on the gauge.

Diagnosis Of Gauge Failures

Circuits for three common gauges are shown in Fig. 86.

Diagnose the failures of gauges as given below.

If a gauge does not register, the cause could be:

1. Lack of current to the gauge.
2. Poor ground connection.
3. Connecting wire grounded to implement.
4. A defective sensing unit or gauge.

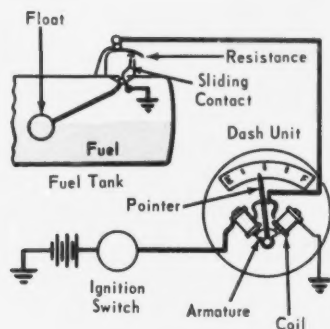
If a gauge consistently registers too high, the cause could be:

1. Poor connection between gauge and connecting wire.
2. Broken connecting wire.
3. Poor ground at sensing unit.
4. Failure of gauge or sensor, usually the sensor.

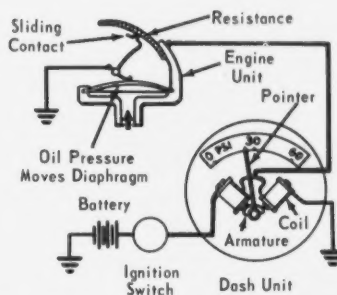
If you cannot determine the cause of the failure, take the machine to a service shop for testing. If you find that a gauge or sensing unit is defective, replace it.

Indicator lamps often use small light bulbs which glow to tell of a failure.

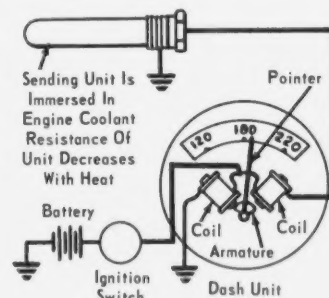
If these lamps do not glow when the starter switch is turned on before starting the engine, first check for a defective bulb. Then, if necessary, check out the other causes given above. (Normally, the lamps should glow when the switch is turned on, then go out shortly after the engine starts—unless there is a problem.)



FUEL GAUGE



OIL PRESSURE GAUGE



OIL TEMPERATURE GAUGE

Fig. 86—Three Gauges And Their Circuits

METERS

Ammeters

The ammeter is an instrument for measuring the strength of an electrical current in terms of amperes.

Normally the ammeter is connected directly to the regulator in series to measure the flow of current through the electrical system.

A typical ammeter consists of a moving magnet with attached needle placed close to a conductor between the ammeter terminals. Current flow through the conductor creates a magnetic field that deflects away from zero on the meter scale.

If an ammeter does not register correctly, replace it with a new ammeter. Do not attempt to repair a defective ammeter.

Voltmeters

Voltmeters are used to indicate the voltage of the electrical input in a circuit (see Fig. 85).

A typical voltmeter consists of a needle attached to a moving iron vane placed inside two stationary coils. The coil winding is parallel with the needle pivot and one winding tends to keep the needle at zero while the other tends to move the needle to the fullscale deflection.

Voltmeters are connected in parallel with the voltage to be measured. Since the voltmeter has a high resistance, adding this component to the circuit will change the total circuit current very little, and the voltage reading obtained shows the true voltage present without the meter in the circuit.

If a voltmeter does not function properly, a new voltmeter must be installed. A defective voltmeter cannot be repaired.

Electric Hour Meter

Electric hour meters are used to show the operating time of a machine while the engine is operating at its rated speed (see Fig. 85).

The hour meter records the time in hours and only operates when the engine is running.

Do not attempt to repair a defective hour meter or its sending unit. When they fail, new components must be installed.

SWITCHES

A switch is a device which opens, closes, or directs current in an electrical circuit.

All switches do basically the same job. The difference is in the way they are operated.

Servicing of Switches

If a switch is defective, always replace it with a new switch. *Do not try to repair a defective switch.* It is usually cheaper and safer to replace it.

IMPORTANT: Always be sure to replace a defective switch with a switch of the same electrical rating. A switch with too high or too low a rating can burn out an electrical circuit.

ELECTRIC MOTORS

Small d.c. electrical motors are used to perform auxiliary functions on some machines. For example, motors are used to operate air conditioner blower, ventilating and heating fans (Fig. 87) and windshield wipers.

Take defective motors to a good electrical shop for servicing by trained technicians.

CIGARETTE LIGHTERS

The cigarette lighter contains a heating element

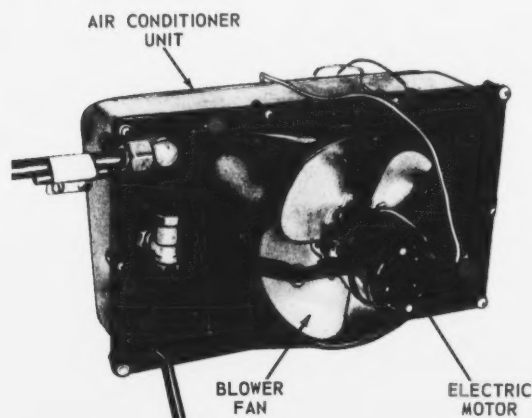


Fig. 87—Electric Motor Used To Operate Air Conditioner Blower Fan

which contacts the electrical circuit when the lighter is pushed in. This causes the element to heat up and glow. The element will remain heated long enough to permit lighting a cigarette or cigar.

The lighter employs a circuit breaker to cut off the electrical current to the lighter element when it has heated to its peak.

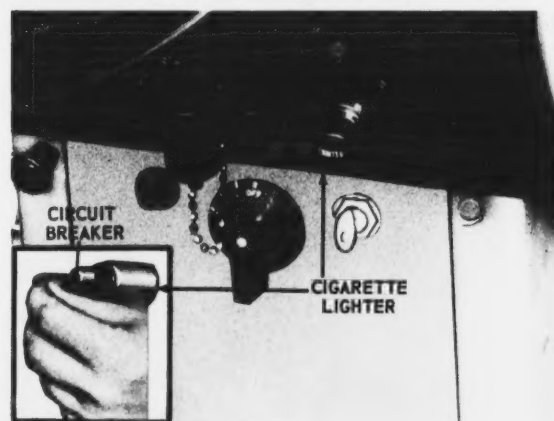
Failure of the cigarette lighter may be caused by a broken wire, disconnected wire, burned-out element, defective lighter shell, or a tripped circuit breaker.

Some circuit breakers on lighters are equipped with a reset opening (Fig. 88). If the lighter fails to operate, the circuit breaker may be open and must be reset.

To do this, insert a small wire in the small hole in the end of the lighter as shown and push in against the spring tension.

If a lighter has a burned-out element or a defective shell, these parts must be replaced.

Fig. 88—Resetting Circuit Breaker On Cigarette Lighter



STEREO TAPE PLAYER

1. If the operator's cab is equipped with a stereo tape player, clean the tape head occasionally. After many hours of operation, brownish colored oxides from the tapes will accumulate on the tape head (Fig. 89).
2. To remove this accumulation, use a non-abrasive cleaning cartridge as instructed on the cartridge.
3. If a cleaning cartridge is not available, use a cotton swab soaked with isopropyl (rubbing) alcohol.
4. Press on the motor switch with a pencil when cleaning the capstan. Clean the channel switch contacts also.

IMPORTANT: Do not use any other solvents or cleaners unless they are specifically designed for cleaning tape heads. NEVER use anything that would scratch

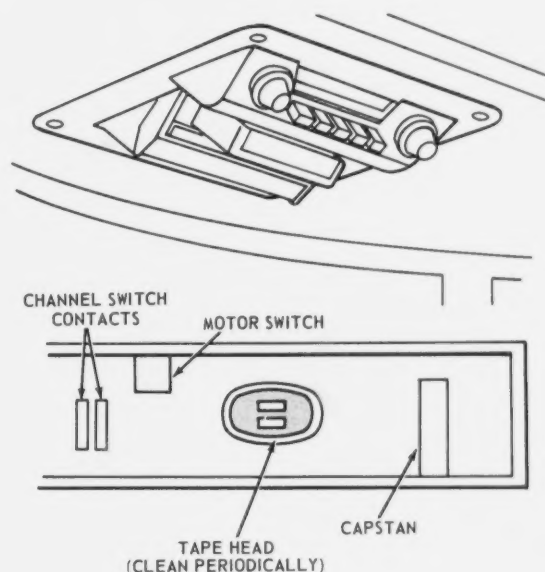


Fig. 89—Tape Player Head

or mar the tape head. Do not use a magnetized tool on the switch. The tape head may become magnetized and increased background noise and loss of high frequency response will result. When this happens, use a demagnetizer at the tape head as instructed by the manufacturer.

CLEANING THE MACHINE

The operator's manual may not mention cleaning the machine. However, regular cleaning will pay off in pride, protection against dirt and chemicals, extra safety, and in general longer life for the equipment.

Paint can be damaged by long exposure to oil, grease, fertilizers, and sprays.

Grease and oil can accumulate and collect dirt which works its way into bearings and other precision parts. Grease on steps and handholds is also a safety hazard.

Cleaning also helps reveal leaks in the cooling system, engine blocks, hydraulic lines, and other parts.

Thoroughly clean the entire machine at least once each year or at the end of the working season. Also clean the machine when it gets very dirty or muddy or when it has been used around chemicals such as fertilizers or crop sprays.

TOOLS AND MATERIALS NEEDED

1. Commercial degreaser, (solvent)
2. Small spray gun
3. Putty knife
4. Screwdriver
5. Cleaning cloths
6. Paintbrush and soap
7. Set of open-end wrenches (inch or metric, as required)
8. Pail
9. Water hose equipped with nozzle
10. Wire brush
11. Face and eye protection

HOW TO CLEAN THE MACHINE

There are two ways of cleaning the machine on the farm:

- Commercial degreaser (solvent)
- Diesel fuel

Either method is effective, but the degreaser is somewhat faster and does a better job of cleaning the hard-to-reach places. Neither means is satisfactory for removing mud or other substances that do not contain oil or grease. (*Do not use gasoline.* It is an extremely bad fire hazard.)

Degreasers are available in small spray cans, or you can buy a more concentrated form in quantities of a quart to a gallon or more (Fig. 90). The concentrated degreaser is by far the least expensive since you can dilute it with five to ten parts of diesel fuel. The



Fig. 90—Degreasers Are Available In Small Pressure Cans Or Bulk Concentrate

cleaner your machine, the more dilution you can use. A gallon of the concentrate is enough to clean your machine several times.

If you are using a degreaser, check the instructions on the can. Some are flammable and are dangerous if used in a closed building or near a flame. Materials under pressure also have additional hazards. Such chemicals could be hazardous to skin or eyes. Wear rubber gloves and eye protection.

The procedures for using degreasers or diesel fuel are as follows:

1. Allow machine to cool, if it has been running.

A hot engine will evaporate the cleaning solvent, but an engine that is warm to your touch can be cleaned most easily.

2. Remove hood and side panels if necessary to reach accumulated dirt.

Fig. 91—Use A Putty Knife To Remove Heavy Accumulations Of Grease And Grime



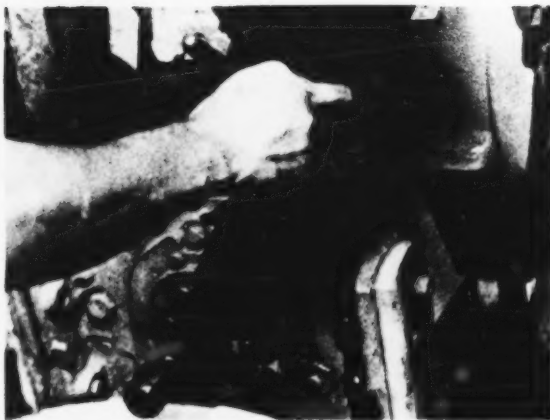


Fig. 92—Apply Solvent On Areas That Need Cleaning

This may not be necessary if most of your machine engine is exposed.

3. Use a putty knife to remove heavy accumulations of grease and grime (Fig. 91).

This will save time and solvent.

4. Apply solvent on areas that need cleaning (Fig. 92).

If you are using a *degreaser* (unless it is in a pressure-type can) apply it with a paint sprayer or insect spray gun in order to get a thin well-distributed film. Apply liberally until the surface has a moist appearance.

If you are using a *diesel fuel* without a degreaser, apply with a paintbrush to help get penetration.

5. Let solvent set approximately 15 minutes.

This gives the solvent time to do an effective job of penetrating and loosening the grease and oil particles.

6. Remove solvent from engine and other surfaces.

With a *degreaser* use a strong stream of water (Fig. 93). Avoid spraying into vents and air intakes. Continue to flush until all milky substance is removed from machine.

If you use *diesel fuel*, remove it with a strong soap and water solution applied with a paintbrush, then flush it off with water.

7. Check for places you have missed.

You may have to use a rag or wire brush to remove some accumulations that did not flush off. Small spots that look dirty while the machine is wet may appear clean enough after drying.

8. Replace the hood and panels that were removed originally.

9. Wipe the machine surfaces dry.



Fig. 93—Degreaser Is Removed With A Strong Water Spray

CHAPTER QUIZ

1. True or false? "Paper air filters may be cleaned in any good detergent."
2. (Fill in the blanks.) If _____ appear in the sight glass of an air conditioner, the refrigerant level is low.
3. Explain how a wheel bearing should be adjusted for tightness.
4. Match the following items covering tires with the correct corresponding item.

A. Overinflation	1. Spinning Wear
B. Underinflation	2. Center Tread Wear
C. Operator Abuse	3. Side Tread Wear
5. When rear tractor tires have the proper weight, what is the correct slippage rate?
6. What should you do just before attaching a grease gun to a grease fitting?

7. What are two effects of tightening a belt drive excessively?

8. Name three reasons for lubricating chains.

9. Which one of the reasons shown below may have caused a quick-blowing fuse to blow if the glass of the fuse is clear?

A. Overload B. Short Circuit C. Open Circuit

10. (Fill in the blanks.) The proper gauge or size of an electrical wire depends upon the _____ of the wire in circuit and the _____ that the wire will carry.

10

Tune-up and Storage



JOHN

ENGINE TUNE-UP

Engine tune-up is probably the most important preventive maintenance that can be performed on a machine. However, most operators make the *mistake of performing tune-up only when the engine is not running satisfactorily*. This is often a costly error because at this point the engine may be worn or damaged until it requires major repair or overhaul. Not only could these costly repairs be avoided by good maintenance, but operating costs could also be saved.

WHAT IS TUNE-UP?

Tune-up is the process of making checks and minor adjustments to improve the operation of the engine.

Tune-up is also *preventive maintenance*. Troubles can be caught early and prevented by checking out the engine before it actually fails.

WHEN SHOULD AN ENGINE BE TUNED?

Regularly! The intervals for tune-up may vary from 500 to 1000 hours or each spring and fall, depending upon the operating conditions. But *regularity* is the key to tuning the engine so that major problems are prevented.

A badly worn engine cannot be tuned up. This is why the engine should first be checked to see if:

- 1) A tune-up will restore it, or
- 2) Major overhaul is needed.

Let's go through a visual inspection and dynamometer test first and then we'll see how tune-up follows it.

VISUAL INSPECTION

By inspecting the engine before tuning it, you can learn a lot about its general condition.

Check out the following items:

1. Oil and Water Leakage

Inspect the engine for any oil or water leaks. If the engine has been using too much oil, this often means an external oil leak. If the engine overheats, look for leaks in the cooling system.

2. Electrical System

Inspect the *battery* for corrosion, cracked case, or leaks at the cell covers.

Remove the cell caps and examine the tops of the battery plates (Fig. 2). If they are covered with a chalky deposit, this means one of three things:

- 1) Electrolyte level has been too low.
- 2) Battery charge has been too low, causing sulfation.
- 3) Battery was charged at too high a rate, boiling out water.

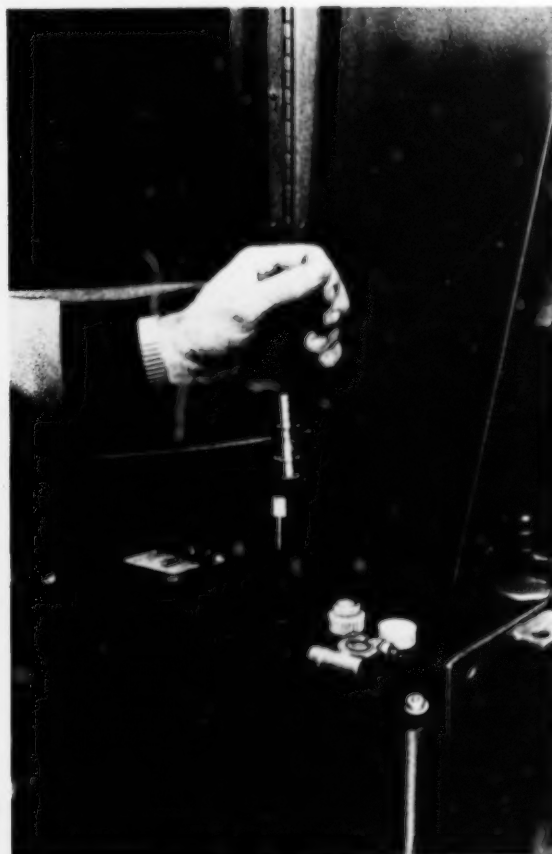


Fig. 1—Tune-Up is Making Checks and Minor Adjustments

Any of these conditions can reduce the life of the battery. If they have gone too far, the battery must be replaced.

Check the *battery cables and connections* for damage and looseness.

Be sure the cables are the right size. Many complaints of poor starting can be traced to battery cables that are too small.

To check for this, operate the starter with the engine cold. If the battery cable gets hot, the cable is probably too small.

Inspect the *wiring harnesses*. If they are too oil-soaked, frayed, or corroded, replace them.

On spark-ignition engines, check the *distributor* for a cracked cap, excessive grease, or other damage.

Check the operation of the alternator or generator *gauge or voltmeter*. It should light or register when the starter switch is turned on.

Failure can be due to a burned-out bulb, an incomplete circuit, or the alternator or generator is not pro-



Fig. 2—Visual Inspection Helps Indicate Whether A Tune-Up or Overhaul is Needed

ducing current. (Lack of current to the battery will show up as a discharged battery.)

If the oil pressure light does not go out, or the gauge doesn't register normal when the engine is running, stop the engine at once and find the cause. Check for low oil level in the crankcase, or a short circuit in the line from sensor to gauge or light.

Stop the engine at once and find the cause.

Lack of engine oil pressure can result in failure of expensive parts inside the engine due to lack of lubrication.

3. Cooling System

Wait until the engine has been idle for several hours and the crankcase oil is cold; then loosen the crankcase drain plug and carefully turn it out to see if any water seeps out. If water is present, locate the cause of the cooling system leak.

Inspect the cooling system for leaks, deteriorated hoses, bent or clogged radiator fins, slipping fan belt,

or any other condition which could result in improper cooling.

4. Air Intake System

Inspect the air intake system for possible leaks or restrictions. If the proper amount of clean air does not reach the engine, performance and durability will be affected.

VISUAL INSPECTION CHECKLIST

☐ OIL AND WATER LEAKAGE

☐ ELECTRICAL SYSTEM

- Battery
- Cables
- Wiring
- Indicator Lights

☐ COOLING SYSTEM

- Water in Crankcase
- External Leaks
- Clogging

☐ AIR INTAKE SYSTEM

- Air Leaks
- Restrictions

☐ FUEL SYSTEM

- Leaks
- Restrictions
- Clogged Filter

☐ STEAM CLEANING

5. Fuel System

Check the fuel system for leaks and for bent or dented lines, which might cause a restriction.

Check the fuel transfer pump sediment bowl. On diesel engines, inspect the fuel filters for dirt, water, or other foreign matter.

6. Steam Cleaning

After checking for leaks, steam clean the engine. This not only helps to recondition the engine, it makes tune-up easier and troubles easier to spot.

DYNAMOMETER TESTS

If possible, test the engine on a dynamometer both *before* and *after* it is turned. Before tune-up, this test gives you the horsepower (kilowatt) output and fuel consumption of the engine as it is. This will help you to

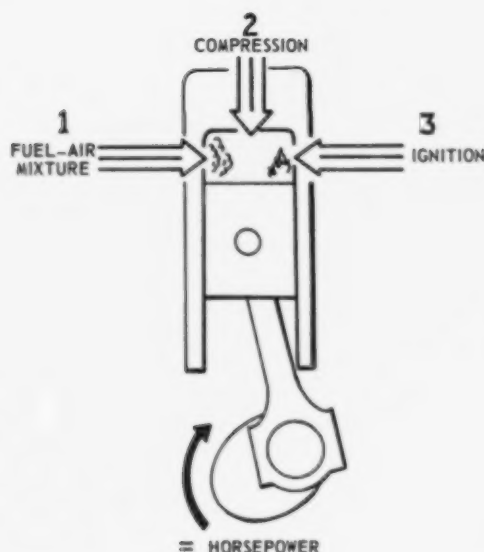


Fig. 3—Three Basic Things Are Needed To Produce Engine Horsepower

determine if a tune-up can restore the engine or whether an overhaul is needed. After tune-up, a dynamometer test will also let you measure the engine's improvement.

Good performance by the engine depends on these basic things:

- 1) Adequate supply of clean air and fuel
- 2) Good compression
- 3) Proper valve and ignition timing for good combustion.

Failure or low performance on any of these factors (Fig. 3) makes it impossible to fully restore the engine.

Therefore, if the dynamometer test shows that any of these three factors is bad—as shown by low power—the engine will have to be reconditioned.

Make the dynamometer test as follows:

1. Connect the machine to the dynamometer (Fig. 4) using the manufacturer's instructions.
2. Operate the engine at about one-half load until the coolant and crankcase oil temperatures are up to normal. (This will take about 30 minutes—but is very important to a good test.)
3. Gradually increase the load on the engine until its speed is reduced to rated load speed as given in the engine Technical Manual.
4. Read the horsepower (kilowatts) on the dynamometer.

5. Compare the power with that given in the engine Technical Manual.

However, do not expect engines to always equal these specifications. But if the engine rates much lower than normal, this is a signal that service is needed.

NOTE: Shop dynamometers cannot be expected to give results on tractors which match the Nebraska tests, for these tests are run under only the most ideal conditions.

While the engine is operating under load, note the outlet of the crankcase ventilating system. If too much vapor appears, also remove the crankcase oil filler cap.

If an excessive amount of vapor or smoke appears here as well as at the vent, there is blow-by in the engine cylinders and they must be reconditioned before the engine will perform at its best.

NOTE: Instruments are available to measure the flow of air and gases through the crankcase ventilating system.

The normal rate of engine vapor flow is specified in the engine Technical Manual.

Any increase in flow over the specified amount indicates crankcase blow-by.

If the blow-by is excessive, have the engine reconditioned for good operation.

Even though the engine develops its rated power using a normal amount of fuel, a tune-up may still improve

Fig. 4—Dynamometer Tests Before Engine Tune-Up



its efficiency. Consider both hours of operation and the conditions under which the engine has been operated. It is far more economical in the long run to tune the engine *before* a lack of performance makes it mandatory.

Remember: Most manufacturers suggest a regular period of operation between tune-ups, such as spring and fall, or every 500 or 1000 hours of operation.

ENGINE TUNE-UP CHART

The following chart gives a capsule of the steps necessary to tune your engine at the recommended intervals. Where they apply, the chapter and page in this text is given for the details of the procedure.

If, after performing these tune-up steps, the engine fails to respond properly, have a service shop make further tests. The engine may require adjustments or repairs that you are not able to perform because of the special tools and knowledge required.

Step No.	Operation	Chapter	Page
1. AIR INTAKE AND EXHAUST SYSTEM			
☐	Clean out precleaner (if used)	2	12
☐	Remove and clean air cleaner	2	12
☐	Inspect exhaust system and muffler	2	22
☐	Check crankcase ventilating system for restrictions	2	25
☐	Check intake manifold for leaks	2	16
☐	Check air intake for leaks or restrictions	2	12
☐	Check radiator for air bubbles or oil indicating compression or oil leakage	5	80
☐	Check cylinder head gasket for leaks	2	26
☐	Retighten cylinder head cap screws	2	20
☐	Adjust valve tappet clearance	2	20
☐	Check engine compression	2	27

Step No.	Operation	Chapter	Page
2. IGNITION SYSTEM (Spark-Ignition Engines)			
☐	Spark Plugs		
	Clean and adjust gap	6	105
☐	Check spark plug wires	6	106
☐	Distributor		
	<i>Check the following items:</i>		
☐	Cap and rotor	6	111
☐	Breaker points	6	111
☐	Breaker point gap	6	112
☐	Cam lubrication	6	112
☐	Distributor timing	6	115
3. FUEL SYSTEMS			
☐	Check fuel lines for leaks or restrictions	3	44, 45
☐	Clean fuel pump sediment bowl	3	43
☐	Clean fuel strainer or filter	3	43
☐	Check radiator for LP-Gas leaking from converter into cooling system	3	46
☐	Drain sediment from gasoline or diesel fuel tank	3	44, 49
☐	Bleed diesel fuel system	3	50
4. LUBRICATING SYSTEM			
☐	Check operation of pressure gauge or light	4	67
☐	Drain and refill crankcase	4	65
☐	Replace oil filter	4	66
5. COOLING SYSTEM			
☐	Check water pump for leaks and excessive shaft endplay	5	77
☐	Inspect radiator hoses	5	77
☐	Clean and flush cooling system	5	81
☐	Refill cooling system with water and permanent antifreeze or rust inhibitor	5	
☐	Replace coolant filter-conditioner (if used)	5	

Step No.	Operation	Chapter	Page
☐	Test thermostat operation	5	83
☐	Check radiator for leaks	5	79
☐	Check condition of fan belt	9	82
6. ELECTRICAL SYSTEM			
☐	Battery		
☐	Clean battery, cables and terminals	6	96
☐	Tighten battery cables and battery hold-down clamps	6	97
☐	Coat battery posts and cable clamps with petroleum jelly	6	98
☐	Check specific gravity of electrolyte and add water to proper level	6	98
☐	Generator or Alternator		
☐	Check belt tension	9	119
7. CLUTCH PEDAL FREE TRAVEL			
☐	Check free travel at clutch pedal	7	136

DYNAMOMETER TESTS AFTER TUNE-UP

The dynamometer test is the final check of overall engine performance after tune-up. It will tell you whether the tune-up has been adequate. Compare it with the dynamometer test made *before* tune-up.

Test for the following things:

1. Engine Horsepower (kilowatts)
2. Exhaust Analysis
Smoke Analysis (Diesel)
Carburetor adjustment (spark-ignition)
3. Fuel Consumption
4. Crankcase Blow-By

Most dynamometer manufacturers have instruments to be used with the dynamometer for checking the above items.

Use the engine Technical Manual for procedures and specifications.

NOTE: If the engine fails to produce the desired power, and an air cleaner restriction test was not made at the beginning, make one now. It is possible that an air restriction is causing the loss of horsepower.



Fig. 5—Dynamometer Tests After Engine Tune-Up

A completely tuned engine should pass the dynamometer test with no problems.

However, the engine should not put out *more* power than it was designed for. Tampering with the engine to get extra power will shorten engine life and raise operating costs. It may also void the engine warranty.

SUMMARY: ENGINE TUNE-UP

Tune-up of an engine may seem like a long ordeal. Actually, most of the items can be checked in a minute or two.

But why check out so many items if the engine has not actually failed?

The answer is that **tune-up is preventive maintenance.**

Before the engine fails, we keep it tuned up so that causes of future failures are corrected early, and possible causes are prevented.

Tune-up catches the problems early—in the farm shop, not in the field.

Shop costs are much cheaper than field costs, and by scheduling the tune-up during a lull in operation, costly downtime at peak periods can be prevented.

Tune-up means that the engine is ready to go and the operator can depend on it for some long and productive hours on the job.

WHY REGULAR TUNE-UP PAYS

Tune-Up Will Not Restore A Badly Worn Engine - Only Major Overhaul Will

BUT:

- Tune-up Improves The Engine
- And Also Prevents Later Problems

HOW?

- Catching Problems Early Means Fewer Service Calls In The Field
- Shop Service Is Cheaper Than Field Calls
- And Shop Service Can Be Scheduled To Avoid Peak Operations

RESULTS:

- Tune-Up Means That The Engine Is Ready To Go
- And Is Dependable For Long, Productive Hours

Fig. 6—Why Regular Engine Tune-Up Pays

STORAGE OF MACHINES

When your machine is not going to be used for several months, it must be prepared for storage to prevent damage to components. Some manufacturers offer storage kits for these long periods of storage. The kits may include rust and corrosion preventives and plastic bags and tape to seal off openings.

For suggested storage procedures, use the charts that follow. They will indicate what steps to perform when preparing your machine for storage and when removing it from storage. *Be sure to observe all safety precautions.*

Where applicable, a chapter and page reference are given for details on each step.

PREPARING MACHINE FOR STORAGE

Step No.	Operation	Chapter	Page
1.	Clean exterior of machine.	9	204
2.	Perform engine tune-up.	10	208
3.	Check coolant for antifreeze protection to minimum anticipated temperature. <i>For those who don't drain and flush each season.</i>	5	
4.	Drain and refill transmission (warm up before draining oil).		

Step No.	Operation	Chapter	Page
5.	After refilling transmission, add corrosion and rust inhibitor to oil, <i>if recommended</i> . Operate transmission until oil is thoroughly circulated.		
6.	Clean and repack wheel bearings.	9	169
7.	Drain and refill hydraulic system with fresh oil.	8	152
	NOTE: Operate hydraulic system until oil is thoroughly heated before draining.		
8.	After refilling hydraulic system, add corrosion and rust inhibitor to oil, <i>if recommended</i> . Operate the system until oil is thoroughly circulated.		
9.	Park machine in selected storage location.		
10.	Drain fuel tank (gasoline and diesel only.) CAUTION: Check with LP-Gas dealer about emptying LP-Gas fuel tank.	3	44, 49
11.	Remove, clean and replace fuel sediment bowl and filters.	3	44, 49
12.	Add two gallons of fuel (mixed with rust inhibitor, if recommended) to the fuel tank.		
13.	Run engine for several minutes and then drain tank again.		
14.	Drain fuel lines and carburetor.		
15.	If recommended, add rust inhibitor to engine crankcase and to air intake.		
16.	With plastic bags and tape, seal ends of air inlet pipe, exhaust pipe, crankcase breather pipe, and hydraulic system breather pipe.		
17.	Remove battery. (Check electrolyte level and specific gravity each month while the battery is in storage. Charge battery when necessary.)	6	95

(Continued)

Step No.	Operation	Chapter	Page
18.	Remove any weights from machine.		
19.	Remove weights from tires. (Drain water if there's danger of freezing.)	9	182
20.	Remove tires if machine is not to be supported off the ground during storage. If you do not wish to remove the tires, raise machine so that tires are off the ground. <i>NOTE: Support machine securely with support stands or blocks.</i>		
21.	Check and inflate tires to normal pressures.		
22.	On machines with conventional dry clutch, block clutch pedal in the disengaged position.		
23.	Release tension on all drive belts and chains.		
24.	Apply grease or rust preventive to chains.		
25.	Coat all exposed metal surfaces, such as axles and hydraulic piston rods, with grease or a rust and corrosion preventive.		
26.	Lubricate all points normally requiring lubrication.		
27.	Check machine over carefully and make a list of parts or repairs needed to make the machine ready for operation when removed from storage. Make these repairs as soon as possible so that little time will be wasted when you remove the machine from storage to use during the next season.		
28.	Clean off rust, then prime and paint these areas to prevent further rusting.		
29.	Cover machine with a tarpaulin if it is not being stored in a building.		

REMOVING MACHINE FROM STORAGE

Step No.	Operation	Chapter	Page
1.	Remove all protective coverings from the machine, including plastic bags on all openings.		
2.	Remove clutch pedal block and allow clutch to engage.		
3.	Check tire inflation pressures.		
4.	Install tires on machine if they were removed.		
5.	Remove supports from machine and lower machine to ground.		
6.	Install battery. Check specific gravity of electrolyte and add water if necessary. Charge battery if specific gravity too low.	6	95
7.	Check crankcase oil level. <i>NOTE: Check operator's manual to see if machine can be operated with rust inhibitor in systems. If not, drain and refill.</i>	4	65
8.	Check hydraulic system oil level.	8	148
9.	Check oil level in transmission, differential, and final drives.	7	138
10.	Adjust tension of belt and chain drives.	9	187, 190
11.	Fill fuel tank with proper fuel.	3	32
12.	Check coolant level.	5	
13.	Start the machine and let it idle for a few minutes. Check to be sure the machine is operating properly before using it.		

CHAPTER QUIZ

1. True or false? "A badly worn engine can be restored by a complete tune-up."
2. Before tuning up an engine, what should be done?
3. When should dynamometer tests be made?

11

Troubleshooting



INTRODUCTION

Troubleshooting is a form of *preventive maintenance* which can help you find and correct minor problems before they become major ones.

The basic procedures for maintaining the machine properly have been covered. However, all machines will fail from time to time. The following charts will help you to identify problems so that you can determine the possible causes and remedies.

These charts list causes of typical failures of the engine, power train, hydraulic system, electrical system, brakes and operator's cab. Where they apply, the chapter and page number is given to guide you to the remedy described in this book.

In most cases, these charts show only problems that you as an operator can remedy. Many problems require expert diagnosis and repair by a service shop. If you can't eliminate the problem, take the machine to a service shop for testing and repair.

The charts are arranged in the following order:

- **Engine**
- **Electrical Systems**
- **Power Train**
- **Hydraulic System**
- **Brakes**
- **Operator's Cab**

TROUBLESHOOTING CHART

Problem	ENGINE		Chap.	Page
	Cause	Remedy		
1. ENGINE HARD TO START OR WILL NOT START	No fuel or improper fuel.	Fill tank. If wrong fuel, drain and refill with proper fuel.	3	32
	Water or dirt in fuel or dirty filters.	Check out fuel supply. Replace or clean filters.	3	
	Air in fuel system (Diesel).	Bleed air from system.	3	50
	Low cranking speed.	Charge or replace battery, or service starter as necessary.	6	
	Improper timing.	Check distributor (Spark-Ignition).	6	115
		Have service shop check injection pump (Diesel).		
	Defective coil or condenser (Spark-Ignition).	Replace coil or condenser.	6	112
	Pitted or burned distributor points (Spark-Ignition).	Clean or replace points.	6	112
	Cracked distributor cap or eroded rotor (Spark-Ignition).	Replace cap or rotor.	6	111
	Distributor wires loose or installed in wrong order (Spark-Ignition).	Push wire into sockets. Install wires in correct firing order.	6	116
	Fouled or defective spark plugs (Spark-Ignition).	Clean and regap plugs or replace them.	6	104
	Poor injection nozzle operation (Diesel).	Have service shop clean or repair nozzles.		
	Liquid fuel in lines (LP-Gas).	Always turn on vapor valve when starting the engine.		
	Engine flooded.	Wait several minutes before attempting to start engine. Do not choke engine again.		
2. ENGINE STARTS BUT WILL NOT RUN PROPERLY	Fuel problem—dirt, air restrictions, or clogged filters.	Check fuel supply, bleed system (Diesel), check for line restrictions, and clean or replace fuel and air filters and screens.	3	
	Carburetor needs adjustment (Spark-Ignition).	Adjust idle and load air-fuel mixtures.	3	40
	Defective coil or condenser (Spark-Ignition).	Replace as necessary.	6	112
	Defective ignition resistor or key switch (Spark-Ignition).	Replace resistor or switch.		
	Pitted or burned distributor points (Spark-Ignition).	Clean or replace points.	6	112
	Fouled or defective spark plugs (Spark-Ignition).	Clean and regap plugs or replace them.	6	104
	Cracked distributor cap or eroded rotor (Spark-Ignition).	Replace cap or rotor.	6	111
3. ENGINE DETONATES (Gasoline)	Wrong type of fuel.	Use proper octane fuel.	3	32

ENGINE—CONTINUED				
Problem	Cause	Remedy	Chap.	Page
4. ENGINE PRE-IGNITES (Gasoline)	Distributor timed too early.	Retime distributor.	6	115
	Distributor advance mechanism stuck.	Free mechanism.	6	111
	Faulty spark plugs or spark plug heat range too high.	Install new plugs that have proper heat range.	6	104
5. ENGINE BACK FIRES - (Spark-Ignition)	Spark plug cables installed wrong.	Install in correct firing order.	6	116
	Carburetor mixture too lean.	Adjust carburetor.	3	40
6. ENGINE KNOCKS	Improper distributor/timing (Spark-Ignition).	Time distributor.	6	115
	Improper injection pump timing (Diesel).	Have service shop check injection pump.		
	Worn engine bearings or bushings.	Have service shop replace.		
	Loose bearing caps.	Have service shop tighten to proper torque.		
	Foreign matter in the cylinder.	Have service shop remove material and repair engine.		
7. ENGINE OVERHEATS	Defective radiator cap.	Replace cap.	5	83
	Radiator core plugged with dirt and debris.	Clean radiator core.	5	79
	Defective thermostat.	Replace thermostat.	5	83
	Loss of coolant.	Check for leaks and correct.	5	83
	Loose fan belt.	Adjust tension.	5	82
	Cooling system has scale deposit build-up.	Use cooling system cleaner to remove scale.	5	81
	Overloaded engine.	Reduce load or shift into a lower gear.		
	Incorrect engine timing.	Time distributor (Spark-Ignition).	6	115
		Have service shop time injection pump (Diesel).		
8. LACK OF POWER	Engine low on oil.	Add oil to the proper level.	4	65
	Wrong type of fuel.	Use recommended fuel.	3	32
	Air cleaner dirty or obstructed.	Clean or replace air cleaner. Remove obstruction.	2	12
	Restriction in fuel lines, filters or carburetor.	Clean plugged parts.	3	
	Wrong type of fuel.	Use recommended type.	3	32
	Frost at fuel-lock strainer (LP-Gas).	Clean strainer.	3	45
	Governor not operating properly.	Have service shop adjust or repair.		
	Valves in engine head leaking.	Have service shop recondition.		
	Incorrect valve clearance.	Adjust clearance.	2	20

ENGINE—CONTINUED				
Problem	Cause	Remedy	Chap.	Page
9. ENGINE USES TOO MUCH OIL	Low engine compression.	Have service shop check and repair engine.	6	115
	Incorrect timing.	Time distributor (Spark-Ignition).		
		Have service shop time injection pump (Diesel).		
	Carburetor improperly adjusted or dirty (Spark-Ignition).	Have service shop clean and adjust carburetor.	6	104
	Wrong spark plugs or plugs fouled (Spark-Ignition).	Clean, regap or replace spark plugs.		
	Distributor points burned (Spark-Ignition).	Replace points and condenser.	6	112
	High engine operating temperature.	See "ENGINE OVERHEATS" above.		
	Low engine operating temperature.	Check thermostat.	5	83
	Vent on fuel tank plugged (Gasoline and Diesel).	Check fuel tank cap.	3	44
	Crankcase oil too light.	Use recommended weight of oil.	4	62
	Worn pistons and rings.	Have service shop recondition.		
	Worn valve guides or stem oil seals.	Have service shop replace.		
	External oil leaks.	Eliminate leaks.	4	67
	Oil pressure too high.	Have service shop adjust pressure.	4	70
	Restricted air intake system.	Check system and relieve restriction.	2	12
10. OIL PRESSURE TOO LOW	See "ENGINE USES TOO MUCH OIL" above.			
11. ENGINE USES TOO MUCH FUEL	Clogged or dirty air cleaner.	Clean or replace air cleaner.	2	12
	Improper type fuel used.	Drain fuel tank and fill with recommended fuel.	3	32
	Engine overloaded.	Reduce load or shift into lower gear.		
	Improper valve clearance.	Adjust valve clearance.	2	20
	Engine out of time.	Time distributor (Spark-Ignition).	6	115
		Have service shop time injection pump (Diesel).		
	Incorrect carburetor adjustment.	Adjust carburetor.	3	40
	Engine not operating at proper temperature.	Check thermostat.	5	83
	Choke in closed position.	Open choke or adjust linkage if necessary.		

ENGINE—CONTINUED				
Problem	Cause	Remedy	Chap.	Page
12. ENGINE EXHAUSTS BLACK OR GRAY SMOKE	Improper type of fuel.	Drain fuel tank and fill with recommended fuel.	3	32
	Clogged or dirty air cleaner.	Clean or replace air cleaner.	2	12
	Defective muffler.	Replace muffler.		
	Engine overloaded.	Reduce load or shift into a lower gear.		
	Fuel injection system faulty.	Have service shop determine cause and repair.		
	Engine out of time.	Time distributor (Spark-Ignition).	6	115
		Have service shop time injection pump (Diesel).		
13. ENGINE EXHAUSTS WHITE SMOKE	Incorrect carburetor adjustment.	Adjust carburetor.	3	40
	Improper type fuel.	Drain fuel tank and fill with recommended fuel.	3	32
	Low engine temperature.	Allow engine to warm up to normal temperatures before operating under load.		
	Defective thermostat.	Replace thermostat.	5	83
	Engine out of time.	Time distributor (Spark-Ignition).	6	115
		Have service shop time injection pump (Diesel).		
ELECTRICAL SYSTEMS				
1. LOW BATTERY OUTPUT	Low electrolyte level.	Add distilled water to proper level.	6	95
	Low specific gravity.	See "LOW BATTERY CHARGE" below.		
	Defective battery cell.	Replace battery.		
	Cracked or broken case.	Replace battery.		
	Low battery capacity.	Replace battery with one of recommended capacity.	6	100
2. BATTERY USES TOO MUCH WATER	Cracked battery case.	Replace battery.		
	Overcharged battery.	Apply load to battery and have voltage regulator checked.		
3. LOW BATTERY CHARGE	Excessive loads from added accessories.	Remove excessive loads or install larger alternator.		
	Excessive engine idling.	Allow engine to idle only when necessary.		
	Continuous drain on battery.	Clean battery top.	6	96
		Check for component grounded or shorted.		
	High resistance in circuit.	Clean and tighten connections. Replace faulty wiring.		

ELECTRICAL SYSTEMS—CONTINUED				
Problem	Cause	Remedy	Chap.	Page
4. LOW CHARGING CIRCUIT OUTPUT	Faulty charging operation.	See "LOW CHARGING CIRCUIT OUTPUT".		
	Slipping drive belts.	Adjust belt tension.	9	187
	Excessively worn or sticking brushes in alternator or generator.	Replace brushes.	6	119
5. NOISY GENERATOR OR ALTERNATOR	Defective alternator or generator.	Replace unit or have service shop repair.		
	Defective or badly worn belt.	Replace belt.		
	Generator brushes not seated.	Seat brushes.	6	119
	Generator commutator worn too much.	Have service shop recondition.		
	Worn or defective bearings.	Have service shop replace bearings.		
6. SLUGGISH STARTING MOTOR OPERATION	Loose mounting or loose pulley.	Tighten mounting and pulley.		
	Misaligned drive belt and pulley.	Realign belt and pulley.	9	188
	Low battery charge.	Charge battery.	6	99
	High resistance in circuit.	Clean and tighten wiring connections.		
	Defective starting motor.	Have service shop repair.		
	Starting motor bearings dry.	Lubricate bearings or replace sealed bearings.		
	Engine oil viscosity too high.	Drain oil and replace with viscosity of oil recommended for cold temperatures.	4	62
7. STARTING MOTOR WILL NOT OPERATE	Low battery charge.	Charge battery.	6	99
	High resistance in circuit.	Clean and tighten connections.		
	Starter safety switch open.	Move shift lever to neutral or park position.		
	Defective or improperly adjusted starter safety switch.	Have service shop adjust or replace switch.		
	Defective starter switch.	Replace switch.		
	Defective starter.	Have service shop check, repair or replace starter.		
8. MISFIRING OF ENGINE	Improper spark plug heat range.	Replace plugs with hotter or colder range plugs as required.	6	104
	Bad plug wiring.	Replace plug wires.	6	106
	Worn spark plug electrodes or fouled plugs.	Clean plugs and regap. Replace plugs if necessary.	6	105
	Defective spark plugs.	Replace plugs.	6	104
	Incorrect distributor timing.	Retime distributor.	6	115
	Insufficient voltage available to spark plugs.	See "LOW VOLTAGE AT SPARK PLUG", below.		

ELECTRICAL SYSTEMS—CONTINUED				
Problem	Cause	Remedy	Chap.	Page
9. LOW VOLTAGE AT SPARK PLUG	Worn or improperly spaced distributor points.	Adjust point gap.	6	112
	Dirty, burned, or pitted points.	Clean or replace points and condenser.	6	112
	Defective condenser.	Replace condenser.	6	112
	Dirt or moisture in distributor cap.	Clean distributor cap.	6	110
	Cracked distributor cap.	Replace cap.	6	112
	Eroded distributor rotor.	Replace rotor.	6	112
	Defective spark plug cables.	Replace cables.	6	106
	Defective ignition coil.	Replace coil.		
	Loose wire connections.	Tighten all connections.		
10. BUILD-UP OF MATERIAL ON DISTRIBUTOR POINTS	Condenser has improper capacity.	Replace with proper condenser.	6	112
11. EXCESSIVE WEAR ON DISTRIBUTOR POINTS RUBBING BLOCK	Inadequate lubricant.	Use cam lubricant to prevent wear.	6	112
12. BURNED DISTRIBUTOR POINTS	Loose lead wire or high resistance in condenser.	Tighten lead or replace condenser.		
	Wrong method of cleaning distributor points.	Use point file and lintless cloth.	6	112
	Oil or foreign material on points.	Clean or replace points.	6	112
13. DIM LIGHTS	High resistance in circuit or poor ground on lights.	Clean and tighten all connections. Replace faulty wiring.		
	Low battery charge.	Charge battery.	6	99
	Defective light switch.	Replace switch.		
14. GENERATOR OR ALTERNATOR INDICATOR LAMP GLOWS INTERMITTENTLY	Excessive resistance in battery lead to unit or regulator.	Clean and tighten all connections. Replace faulty wiring.		
	Excessive internal resistance in generator or alternator.	Replace brushes or take to service department.	6	119
		Have unit repaired or replaced.		
15. OIL PRESSURE INDICATOR LAMP FAILS TO LIGHT	Burned-out bulb.	Replace bulb.		
	Open circuit or excessive resistance in wiring.	Clean and tighten all connections. Replace faulty wiring.		
	Defective lamp body.	Replace lamp body.		
	Faulty oil pressure switch.	Replace switch.		
16. OIL PRESSURE LAMP REMAINS ON WITH STARTING SWITCH OFF	Defective lamp body.	Replace lamp body.		
	Grounded wire to oil pressure switch.	Repair or replace wiring.		
	Faulty oil pressure switch.	Replace switch.		

POWER TRAIN (CLUTCH)			
Problem	Cause	Remedy	Chap. Page
1. CLUTCH SLIPS	Too little clutch pedal free travel.	Adjust clutch pedal free travel.	7 136
	Operator riding clutch pedal.	Do not ride clutch pedal.	
	Worn clutch disks.	See dealer for repair.	
2. CLUTCH GRABS OR CHATTERS		Take the machine to a service shop for repair or adjustment.	
3. CLUTCH SQUEAKS	Clutch release bearing dry.	Lubricate bearing.	7 136
	Clutch actuating mechanism dry.	Lubricate linkage and shafts.	
4. CLUTCH RATTLES AND VIBRATES		Take the machine to a service shop for repair or adjustment.	
POWER TRAIN (MECHANICAL TRANSMISSION)			
1. TRANSMISSION NOISY	Transmission oil level low.	Fill transmission with proper lubricant.	7 138
	Worn or broken gears.	See dealer for repair.	
2. TRANSMISSION HARD TO SHIFT		Take machine to service shop for repair or adjustment.	
3. TRANSMISSION STICKS IN GEAR	Clutch not releasing.	Adjust clutch pedal free travel.	7 136
	Shift linkage binding.	Free linkage.	
	Worn shift linkage.	Have dealer repair.	
4. TRANSMISSION SLIPS OUT OF GEAR		Take machine to service shop for repair or adjustment.	
5. TRANSMISSION LEAKS OIL	Oil level too high.	Drain to proper level.	
	Gaskets damaged or missing.	Have dealer install new gaskets.	
	Drain plug loose.	Tighten drain plug.	
	Lubricant foaming excessively.	Use recommended lubricant.	
POWER TRAIN (HYDRAULIC ASSIST TRANSMISSION)			
1. MACHINE WON'T MOVE	Cold weather starting clutch disengaged.	Engage clutch.	
	Park lock engaged.	Release lock.	
	Control linkage binding or disconnected.	Free linkage or connect linkage.	
	Oil filter plugged.	Replace oil filter.	7 139
2. SHIFTS ERRATICALLY	Shift control disconnected or binding.	Free controls or connect disconnected parts.	
3. LOW SYSTEM PRESSURE	Plugged oil filter.	Replace filter.	7 139
	Low oil level.	Fill to proper level.	7 139
4. TRANSMISSION OVERHEATING	Reservoir oil level too low or too high.	Bring oil level to proper level.	
	Plugged oil filter.	Replace filter.	7 139
	Plugged core in oil cooler.	Clean core.	

POWER TRAIN (TORQUE CONVERTER)			
Problem	Cause	Remedy	Chap. Page
1. OVERHEATING	Oil level too low. Machine overloaded. Plugged oil cooler core.	Fill to proper level. Reduce load. Clean core.	7 138
2. NOISY	Major failure or maladjustment.	Take machine to service shop for repair or adjustment.	
3. OIL LEAKS	Loose bolts or damaged gaskets. Loose fittings or oil lines.	Tighten bolts. Have service shop replace gaskets. Tighten fittings and lines.	
4. MACHINE LACKS POWER OR ACCELERATION	Major failure or maladjustment.	Take machine to service shop for repair or adjustment.	
POWER TRAIN (HYDROSTATIC TRANSMISSION)			
1. MACHINE WILL NOT MOVE	System low on oil. Faulty control linkage. Disconnected oil line. Mechanical failure.	Fill to proper level. Free linkage. Reconnect oil line. See dealer for repair.	
2. NEUTRAL HARD TO FIND	Faulty speed control linkage.	Adjust control linkage.	
3. SYSTEM OVERHEATING	Oil level too low. Oil cooler core plugged. Engine fan belt slipping or broken.	Fill to proper level. Clean core. Tighten or replace belt.	
4. SYSTEM NOISY	Air in system.	Check oil supply; fill if low. Check for loose fittings and tighten.	
5. SLUGGISH ACCELERATION AND DECELERATION	Air in system.	Check oil supply; fill if low. Check for loose fittings and tighten.	
6. HARD SHIFTING	Speed control lever not in neutral.	Position lever in neutral.	
POWER TRAIN (DIFFERENTIAL)			
1. NOISY	Oil level too low.	Fill to proper level.	7 138
2. TURNING DIFFICULTY	Differential lock won't release, Brakes dragging, or differential lock stuck.	Take machine to service shop for repairs.	
3. MECHANICAL LOCK DOESN'T HOLD	Linkage not in adjustment.	Take machine to service shop for repairs or adjustment.	
4. HYDRAULIC LOCK DOESN'T HOLD	Valve malfunction or linkage not in adjustment.	Take machine to service shop for repairs or adjustment.	

HYDRAULIC SYSTEM				
Problem	Cause	Remedy	Chap.	Page
1. SYSTEM DOESN'T OPERATE	Little or no oil in system.	Fill to proper level. Check system for leaks.	8	148
	Oil of wrong viscosity.	Drain and refill system with proper oil.	8	152
	Oil filter plugged.	Replace filter.	8	154
	Restriction in system.	Take machine to service shop for repairs.		
	Oil leaks.	Tighten fittings and lines.		
	Slipping or broken pump drive belt.	Tighten or replace belt.		
2. SYSTEM OPERATES ERRATICALLY	Air in system.	Check for leaks and tighten fittings and lines.		
	Cold oil.	Allow system to warm up.		
3. SYSTEM OPERATES SLOWLY	Cold oil.	Allow system to warm up.		
	Oil viscosity too heavy.	Drain and refill system with proper viscosity of oil.	8	142
	Engine speed too slow.	Operate engine at recommended speed.		
	Low oil supply.	Fill to proper level.	8	148
	Air in system.	Check for leaks and tighten fittings and lines.		
4. SYSTEM OPERATES TOO FAST	Adjust cylinder ram speed. Adjust or repair.	See operator's manual. Adjust per operator's manual. For repair, see dealer.		
5. SYSTEM OVERHEATING	Operator holding controls in power position too long.	Return controls to neutral when not in use.		
	Incorrect oil viscosity.	Use recommended viscosity of oil.	8	142
	Low oil level.	Fill to proper level. Check for leaks.		
	Dirty oil.	Drain and refill with clean oil.	8	152
	Oil cooler core plugged or dirty.	Clean core.	8	149
6. FOAMING OIL	Low oil level.	Fill to proper level. Check for leaks.	8	149
	Water in oil.	Drain and replace oil.	8	152
	Wrong kind of oil.	Drain and replace with recommended oil.	8	142
	Air leak.	Tighten lines and fittings.	8	156
7. NOISY PUMP	Low oil level.	Fill to proper level. Check for leaks.	8	152
	Air in oil.	Check for leaks. Tighten lines and fittings.	8	156
8. COMPONENTS LEAKING	Failure of major parts.	Take machine to service shop for repairs.		

BRAKES				
Problem	Cause	Remedy	Chap.	Page
1. BRAKES NOT HOLDING	Glazed, greasy or worn linings.	Replace linings.		
2. BRAKES NOT RELEASING	Cables or linkage binding.	Adjust linkage and cables.	9	176
	Foreign material lodged in brake mechanism.	Remove material.		
3. PEDAL BOUNCES OR SPONGY	Hydraulic brakes: air in system.	Bleed brakes.	8, 9	154, 178
4. NO BRAKES	Hydraulic brakes: air in system.	Bleed brakes.	8, 9	154, 178
	Manual brakes: linings worn or linkage out of adjustment.	Replace linings or adjust linkage.	9	178
	Power brakes: accumulator discharged.	Take machine to service shop for repairs.		
5. MACHINE PULLS TO ONE SIDE	Brakes adjusted unevenly.	Adjust brakes.	9	178
6. HYDRAULIC BRAKES OPERATE ERRATICALLY	Contaminated fluid.	Drain and clean system. Refill system with proper fluid. Bleed brakes.	8, 9	154, 178
OPERATOR'S CAB				
1. BLOWER NOT KEEPING DUST OUT	Defective seal around filter.	Check seal condition. Check filter for proper installation.		
	Defective or dirty filter.	Replace or clean filter.	9	164
	Air leaks into cab.	Check cab for leaks. Plug leaks.		
	Blower air flow too low.	See "BLOWER AIR FLOW TOO LOW".		
2. BLOWER AIR FLOW TOO LOW	Clogged filter or air intake screen.	Clean filter or intake screen.	9	164
3. HEATER WILL NOT HEAT	Air trapped in heater core.	Bleed air from heater.		
	Defective thermostat in engine.	Replace thermostat.	5	83
	Air conditioner turned on.	Turn off air conditioner.		
4. HEATER WILL NOT SHUT OFF	Heater hoses connected improperly.	Change hose connections.		
5. AIR CONDITIONER WILL NOT COOL	Blower air flow too low.	See "BLOWER AIR FLOW TOO LOW".		
	Compressor belt slipping.	Tighten belt.	9	167
	Lack of refrigerant in system.	Check sight glass and have system recharged.	9	167
	Evaporator core plugged.	Clean core.	9	166
	Condenser core clogged.	Clean core.	9	166
	Heater turned on.	Turn off heater.		
	Compressor not running.	Check fuse.		

Glossary Suggested Readings Index



GLOSSARY

A

ABRASION—Wearing or rubbing away of a part.

ACCUMULATOR—A container which stores fluids under pressure as a source of hydraulic power. It may also be used as a shock absorber.

ADDITIVE—A substance added to oil to give it certain properties. For example, a material added to engine oil to lessen its tendency to congeal or thicken at low temperatures.

AIR CLEANER—A device for filtering, cleaning, and removing dust from the air admitted to an engine.

AIR CONDITIONING—Absolute control of temperature and humidity; air conditioning in true sense used only in some laboratories and manufacturing plants where temperature and humidity control are very critical. Ordinary usage in homes, buildings, and vehicles means control of temperature and removal of moisture by condensation; more correct designation is refrigeration.

ALIGNMENT—an adjustment to a line or to bring into a line.

ALTERNATOR—A device which converts mechanical energy into electrical energy.

ALTERNATING CURRENT (A.C.)—A flow of electrons which reverses its direction of flow at regular intervals in a conductor.

AMBIENT TEMPERATURE—Temperature of surrounding air. In air conditioning, it refers to *outside* air temperature.

AMMETER—An instrument for measuring the flow of electrical current in amperes. Ammeters are usually connected in series with the circuit to be tested.

AMPERE—A unit of measure for the flow of current in a circuit.

AMPERE-HOUR—A unit of measure for battery capacity. It is obtained by multiplying the current (in amperes) by the time (in hours) during which current flows. For example, a battery which provides 5 amperes for 20 hours is said to deliver 100 ampere-hours.

ANTIFREEZE—A material such as ethylene glycol, alcohol, etc., added to water to lower its freezing point.

AUTOMATIC TRANSMISSION—A transmission in which gear or ratio changes are self-activated.

AXIAL—Parallel to the shaft or bearing bore.

AXLE—The shaft or shafts of a machine upon which the wheels are mounted.

B

BACKFIRE—Ignition of the mixture in the intake manifold by flame from the cylinder such as might occur from a leaking inlet valve.

BACKLASH—The clearance or "play" between two parts, such as meshed gears.

BACK-PRESSURE—A resistance to free flow, such as a restriction in the exhaust line.

BAR—A unit of pressure equal to 100 kiloPascals or 1.02 kg/cm². Approximately equal to 14.5 psi.

BEARING—The supporting part which reduces friction between a stationary and rotating part.

BLEED—The process by which air is removed from a fuel or hydraulic system.

BLOW-BY—A leakage or loss of compression past the piston ring between the piston and the cylinder.

BOILING POINT—The temperature at which bubbles or vapors rise to the surface of a liquid and escape.

BREAK-IN—The process of wearing in to a desirable fit between the surfaces of two new or reconditioned parts.

BRUSH—A device which rubs against a rotating slip ring or commutator to provide a passage for electric current to a stationary conductor.

BYPASS—An alternate path for a flow of air or liquid.

C

CAMSHAFT—The shaft containing lobes or cams to operate the engine valves.

CARBURETOR—A device for automatically mixing gasoline fuel in the proper proportion with air to produce a combustible vapor.

CARBURETOR "ICING"—A term used to describe the formation of ice on a carburetor throttle plate during certain atmospheric conditions.

CENTIMETER—A unit of length equal to 0.01 meter, or approximately 0.39 inches (symbol: cm).

CETANE—Measure of ignition quality of diesel fuel—at what pressure and temperature the fuel will ignite and burn.

CHARGE—To restore the active materials in a battery by the passage of direct current through it.

CHOKE—A device such as a valve placed in a carburetor air inlet to restrict the volume of air admitted.

CIRCUIT BREAKER—A device to protect an electrical circuit from overloads.

CLEARANCE—The space allowed between two parts, such as between a shaft and its bearing.

CLUTCH—A device for connecting and disconnecting the engine from the transmission or for a similar purpose in other units.

COIL (IGNITION)—A transformer which steps up voltage to produce ignition sparks.

COLD RATING—The cranking load capacity of a battery at low temperatures.

COMBUSTION—The process of burning.

COMBUSTION CHAMBER—The volume of the cylinder above the piston with the piston on top center.

COMPRESSION—The reduction in volume or the "squeezing" of a gas. As applied to metal, such as a coil spring, compression is the opposite of tension.

COMPRESSION RATIO—The volume of the combustion chamber at the end of the compression stroke as compared to the volume of the cylinder and chamber with the piston on bottom center. Example: 8 to 1.

CONDENSATION—Process of changing a gas to a liquid.

CONDENSER—An automotive term which describes a capacitor.

CONDUCTOR—A substance or body through which an electrical current can be transmitted.

CONSTANT MESH TRANSMISSION—A transmission in which the gears are engaged at all times, but shifts are made by sliding collars which lock together two or more gears.

CONTRACTION—A reduction in mass or dimension; the opposite of expansion.

CONVERTER—As used in connection with LP-Gas, a device which converts or changes LP-Gas from a liquid to a vapor for use by the engine.

COOLANT—A liquid circulated through an engine to absorb and release heat. Usually a mixture of water and antifreeze or rust inhibitor.

COOLER (OIL)—A heat exchanger which removes heat from a fluid. (See "Heat Exchanger.")

COUPLING—A connecting means for transferring movement from one part to another; may be mechanical, hydraulic or electrical.

CRANKCASE—The lower housing in which the crankshaft and many other parts of the engine operate.

CRANKCASE DILUTION—When unburned fuel finds its way past the piston rings into the crankcase oil, where it dilutes or "thins" the engine lubricating oil.

CRANKSHAFT—The main drive shaft of an engine which takes reciprocating motion and converts it to rotary motion.

CURRENT—Movement of electricity along a conductor. Current is measured in amperes.

CYLINDER—A round hole which receives the engine piston. Also a device for converting fluid power into linear or circular motion.

CYLINDER HEAD—A detachable portion of an engine fastened securely to the cylinder block which contains all or a portion of the combustion chamber.

D

DEAD CENTER—The extreme top or bottom position of the crankshaft throw at which the piston is not moving in either direction.

DETERGENT—A compound of a soap-like nature used in engine oil to remove engine deposits and hold them in suspension in the oil.

DETONATION—A too-rapid burn or explosion of the fuel-air mixture in engine cylinders. It becomes audible through a vibration of the combustion chamber walls and is sometimes confused with a "ping" or spark "knock."

DIAGNOSIS—In engine service, the use of instruments to "trouble shoot" the engine parts to locate the cause of a failure.

DIAL INDICATOR—A type of micrometer where the readings are indicated on a dial rather than on a thimble as in a micrometer.

DIESEL ENGINE—Named after its developer, Dr. Rudolph Diesel. This engine ignites fuel in the cylinder from the heat generated by compression. The fuel is an "oil" rather than gasoline, and no spark plug or carburetor is required.

DIFFERENTIAL GEAR—The gear system which permits one drive wheel to turn faster than the other.

DILUTION—See Crankcase Dilution.

DIRECT CURRENT (D.C.)—A steady flow of electrons moving steadily and continually in the same direction along a conductor from a point of high potential to one of lower potential. It is produced by a battery, generator, or rectifier.

DIRECT DRIVE—Direct engagement between the engine and driveshaft where the engine crankshaft and the driveshaft turn at the same rpm.

DISCHARGE—To remove electrical energy from a charged body such as a capacitor or battery.

DISPLACEMENT—The volume displaced by one complete stroke or revolution (of a pump, motor, or engine cylinder).

DISTRIBUTOR (IGNITION)—A device which directs the ignition of an engine.

DRAWBAR HORSEPOWER (Kilowatts)—Measure of the power of a machine at the drawbar hitch point.

DRIVE LINE—The universal joints, drive shaft and other parts connecting the transmission with the driving axles.

DYNAMOMETER—A test unit for measuring the actual power produced by an engine.

E

ELECTRICITY—The flow of electrons from atom to atom in a conductor.

ELECTROLYTE—Any substance which, in solution, is dissociated into ions and is thus made capable of conducting an electrical current. The sulfuric acid-water solution in a storage battery is an electrolyte.

ELECTRONIC IGNITION—An ignition system for spark-ignition engines which uses a reluctor, sensor, and ignition controller to control the timing of the spark.

ENDPLAY—The amount of axial or end-to-end movement in a shaft due to clearance in the bearings.

ENGINE—The prime source of power generation used to propel the machine.

ENGINE DISPLACEMENT—The sum of the displacement of all the engine cylinders. See "Displacement."

EVAPORATION—The process of changing from a liquid to a vapor, such as boiling water to produce steam. Evaporation is the opposite of condensation.

EXHAUST GAS ANALYZER—An instrument for determining the efficiency with which an engine is burning fuel.

EXHAUST MANIFOLD—The passages from the engine cylinders to the muffler or exhaust pipe which conduct exhaust gases away from the engine.

EXPANSION—An increase in size. For example, when a metal rod is heated it increases in length and perhaps also in diameter. Expansion is the opposite of contraction.

F

FEELER GAUGE—A metal strip or blade finished accurately with regard to thickness used for measuring the clearance between two parts; such gauges ordinarily come in a set of different blades graduated in thickness by increments of 0.001 inch (or mm).

FILTER—A device which removes solids from a fluid.

FLOW METER—A hydraulic testing device which gauges either flow rate, total flow, or both.

FLUID DRIVE—A pair of vaned rotating elements held in position close to each other without touching. Rotation is imparted to the driven member by the driving member through the resistance of a body of oil. (See Chapter 6 on Torque Converters.)

FOOT-POUND (ft-lb)—This is a measure of the amount of energy or work required to lift one pound a distance of one foot; approximately equal to 1.36 joule.

FOUR-CYCLE ENGINE—Also known as Otto cycle, where an explosion occurs every other revolution of the crankshaft; a cycle being considered as $\frac{1}{2}$ revolution of the crankshaft. These strokes are (1) intake stroke; (2) compression stroke; (3) power stroke; (4) exhaust stroke.

FREE-WHEELING CLUTCH—A mechanical device which will engage the driving member to impart motion to a driven member in one direction but not the other. Also known as an "overrunning clutch."

FUEL KNOCK—Same as Detonation.

FUSE—A replaceable safety device for an electrical circuit. A fuse consists of a fine wire or a thin metal strip encased in glass or some fire-resistant material. When an overload occurs in the circuit, the wire or metal strip melts, breaking the circuit. Also see "Circuit Breaker."

G

GAS—A substance which can be changed in volume and shape according to the temperature and pressure applied to it. For example, air is a gas which can be compressed into smaller volume and into any shape desired by pressure. It can also be expanded by the application of heat.

GEAR—A cylinder- or cone-shaped part having teeth on one surface which mate with and engage the teeth of another part which is not concentric with it.

GEAR RATIO—The ratio of the number of teeth on the larger gear to the number of teeth on the smaller gear.

GENERATOR—A device which converts mechanical energy into electrical energy.

GOVERNOR—A device to control and regulate engine speed. May be mechanical, hydraulic, or electrical.

GROUND—A ground occurs when any part of a wiring circuit unintentionally touches a metallic part of the machine frame.

GROUNDING CIRCUIT—A connection of any electrical unit to the frame, engine, or any part of the tractor or machine, completing the electrical circuit to its source.

H

HECTARE—A measurement of area equal to 10,000 square meters, or approximately 2.47 acres (symbol: ha).

HORSEPOWER (hp)—The energy required to lift 550 pounds one foot in one second; approximately 0.746 kilowatts.

HYDRAULIC PRESSURE—Pressure exerted through the medium of a liquid.

HYDROMETER—An instrument for measuring battery specific gravity. A hydrometer is used to test the specific gravity of the electrolyte in a battery.

I

IDLE—Refers to the engine operating at its slowest speed with the machine not in motion.

INHIBITOR—A material to restrain some unwanted action, such as a rust inhibitor which is a chemical

added to cooling systems to retard the formation of rust.

INJECTION PUMP (Diesel)—A device by means of which the fuel is metered and delivered under pressure to the engine injector.

INJECTOR (Diesel)—An assembly which receives a metered charge of fuel from another source at relatively low pressure, then is actuated to inject the charge of fuel into a cylinder or chamber at high pressure and at the proper time. Also called "injection nozzle."

INPUT SHAFT—The shaft carrying the driving gear by which the power is applied, as to the transmission.

INSULATOR—A substance or body that resists the flow of electrical current through it. Also see "Conductor."

INTAKE MANIFOLD—The passages which conduct the fuel-air mixture from the carburetor to the engine cylinders.

INTAKE VALVE—A valve which permits a fluid or gas to enter a chamber and seals against exit.

INTERNAL COMBUSTION—The burning of a fuel within an enclosed space.

J

JOULE—A unit of energy or work approximately equal to 0.102 kg·m, or about 0.7377 ft-lbs (symbol: J).

K

KILOGRAM—A unit of mass (weight) approximately equal to 2.2 pounds (symbol: kg).

KILOMETER—A unit of distance equal to 1000 meters, or approximately 0.62 miles (symbol: km).

KILOPASCAL—A unit of pressure equal to 0.01 bar, or approximately 0.145 psi (symbol: kPa).

KILOWATT—A measurement of work equal to 1000 watts, or approximately 1.34 horsepower (symbol: kW).

KNOCK—A general term used to describe various noises occurring in an engine; may be used to describe noises made by loose or worn mechanical parts, preignition, detonation, etc.

L

LINKAGE—Any series of rods, yokes, and levers, etc., used to transmit motion from one unit to another.

LITER—A unit of volume equal to 1000 cubic centimeters, or approximately 0.26 gallons (symbol: L).

LOW SPEED—The gearing which causes the greatest number of revolutions of the engine as compared to the driving wheels.

LP-GAS, LIQUEFIED PETROLEUM GAS—Made usable as a fuel for internal combustion engines by compressing volatile petroleum gases to liquid form. When so used, must be kept under pressure or at low temperature in order to remain in liquid form, until used by the engine.

M

MANIFOLD—A pipe or casting with multiple openings used to connect various cylinders to one inlet or outlet.

MANOMETER—A device for measuring a vacuum. It is a U-shaped tube partially filled with fluid. One end of the tube is open to the air and the other is connected to the chamber in which the vacuum is to be measured. A column of Mercury 30 in. high equals 14.7 lbs. per square in. which is atmospheric pressure at sea level. Readings are given in terms of inches of Mercury.

MECHANICAL EFFICIENCY (Engine)—The ratio between the indicated horsepower and the brake horsepower of an engine.

METER—A unit of length equal to 100 centimeters, or approximately 39.4 inches (symbol: m).

MISFIRING—Failure of an explosion to occur in one or more cylinders while the engine is running; may be a continuous or intermittent failure.

MOTOR—This term should be used in connection with an electric motor and should not be used when referring to the *engine* of a machine. An electric motor converts electrical energy to mechanical energy. A hydraulic motor converts hydraulic energy to mechanical energy, usually rotation.

MUFFLER—A chamber attached to the end of the exhaust pipe which allows the exhaust gases to expand and cool. It is usually fitted with baffles to porous plates and serves to subdue much of the noise created by the exhaust.

N

NEWTON—A unit of force equal to approximately 9.8 kilograms, or 4.45 pounds force (symbol: N).

O

OCTANE—Measurement which indicates the tendency of a gasoline or LP-Gas fuel to detonate or knock.

OHMMETER—An instrument for measuring the resistance in ohms of an electrical circuit.

OPEN OR OPEN CIRCUIT—An open or open circuit occurs when a circuit is broken, such as by a broken wire or open switch, interrupting the flow of current

through the circuit. It is much like a closed valve in a water system.

OUTPUT SHAFT—The shaft or gear which delivers the power from a device, such as a transmission.

P

PINION—A small gear having the teeth formed in the hub.

PISTON—A cylindrical part closed at one end which is connected to the crankshaft by the connecting rod. The force of the expansion in the cylinder is exerted against the closed end of the piston, causing the connecting rod to move the crankshaft. A cylindrical part of a hydraulic cylinder which is attached to the rod. Oil entering the cylinder under pressure moves the piston thus extending the rod. If oil pressure can be applied to both sides of the piston, it is called a double-acting cylinder and it can provide a force in two directions.

PISTON RING—An expanding ring placed in the grooves of the piston to seal off the passage of fluid or gas past the piston.

PLANETARY GEARS—A system of gearing which is modeled after the solar system. A pinion is surrounded by an internal ring gear and planet gears are in mesh between the ring gear and pinion around which all revolves.

POLARITY—A collective term applied to the positive (+) and negative (−) ends of a magnet or electrical mechanism such as a coil or battery.

POUR POINT—The lowest temperature at which a fluid will flow under specific conditions.

POWER SHIFT TRANSMISSION—A transmission in which gear changes are selected manually but are power actuated; no master clutch is involved.

PREIGNITION—Ignition occurring earlier than intended. For example, the explosive mixture being fired in a cylinder as by a flake of incandescent carbon before the electric spark occurs.

PRELOAD—A load within the bearing, either purposely built in, or resulting from adjustment.

PRESSURE—Force of a fluid per unit area, usually expressed in pounds per square inch (psi), bar, or kilopascals (kPa).

PUMP—A device which converts mechanical force into hydraulic fluid power. Basic design types are gear, vane, and piston units. Or, a mechanical device for moving fluids such as fuel.

R

RATED HORSEPOWER—Value used by the engine manufacturer to rate the power of his engine, allowing for safe loads, etc.

RATIO—The relation or proportion that one number bears to another.

REGULATOR—A device which controls the flow of current or voltage in a circuit to a certain desired level.

RELAY—An electrical switch which opens and closes a circuit automatically.

REMOTE—A hydraulic function such as a cylinder which is separate from its supply source. Usually connected to the source by flexible hoses.

RESERVOIR—A container for keeping a supply of working fluid in a hydraulic system.

RING GEAR—A gear which surrounds or rings the sun and planet gears in a planetary system. Also the name given to the spiral bevel gear in a differential.

S

SCALE—A flaky deposit occurring on steel or iron. Ordinarily used to describe the accumulation of minerals and metals accumulating in an engine cooling system.

SENDING UNIT—A device, usually located in some part of an engine or other system, to transmit information to a gauge on an instrument panel.

SHIM—Thin sheets used as spacers between two parts, such as the two halves of a bearing.

SHORT (OR SHORT CIRCUIT)—This occurs when one part of a circuit comes in contact with another part of the same circuit, diverting the flow of current from its desired path.

SLIDING GEAR TRANSMISSION—A transmission in which gears are moved on their shafts to change gear ratios.

SLUDGE—A composition of oxidized petroleum products along with an emulsion formed by the mixture of oil and water. This forms a pasty substance and clogs oil lines and passages and interferes with engine lubrication.

SOLVENT—A solution which dissolves some other material. For example, water is a solvent for sugar.

SPARK PLUGS—Devices which ignite the fuel by a spark in a spark-ignition engine cylinder.

SPECIFIC GRAVITY—The ratio of a weight of any volume of a substance to the weight of an equal volume of some substance taken as a standard, usually water for solids and liquids. When a battery electrolyte is tested, the result is the specific gravity of the electrolyte.

STORAGE BATTERY—A group of electrochemical cells connected together to generate electrical energy. It stores the energy in a chemical form.

STRAINER—A coarse filter.

STROKE—The distance moved by the piston in an engine or hydraulic cylinder.

SUCTION—Suction exists in a vessel when the pressure is lower than the atmospheric pressure; also see Vacuum.

SULFATION—The formation of hard crystals of lead sulfate on battery plates. The battery is then "sulfated."

SYNCHROMESH TRANSMISSION—Transmission gearing which aids the meshing of two gears by causing the speed of both gears to coincide at the same time.

SYNCHRONIZE—To cause two events to occur at the same time. For example, to time a mechanism so that two or more sparks will occur at the same instant.

T

TACHOMETER—An instrument for measuring rotary speed; usually revolutions per minute.

THERMOSTAT—A heat-controlled valve used in the cooling system of an engine to regulate the flow of water between the cylinder block and the radiator.

TORQUE—The effort of twisting or turning.

TORQUE CONVERTER—A turbine device utilizing a rotary pump, one or more reactors (stators) and a driven circular turbine or vane whereby power is transmitted from a driving to a driven member by hydraulic action. It provides varying drive ratios; with a speed reduction, it increases torque.

TORQUE WRENCH—A special wrench with a built-in indicator to measure the applied turning force or torque.

TRANSMISSION—An assembly of gears, or other elements which gives variations in speed or direction between the input and output shafts.

TROUBLESHOOTING—A process of diagnosing the source of the trouble or troubles through observation and testing.

TUNE-UP—A process of accurate and careful adjustments to obtain the best performance from a machine.

TURBOCHARGER—A blower or pump which forces air into the engine cylinders at higher-than-atmospheric pressure. The increased pressure forces more air into the cylinder, thus enabling more fuel to be burned and more power produced.

V

VACUUM—A perfect vacuum has not been created as this would involve an absolute lack of pressure. The term is ordinarily used to describe a partial vacuum; that is, a pressure less than atmospheric pressure; in other words a Suction.

VACUUM GAUGE—An instrument designed to measure the degree of vacuum existing in a chamber.

VALVE—A device which controls either 1) pressure of fluid, 2) direction of fluid flow, or 3) rate of flow.

VALVE CLEARANCE—The air gap allowed between the end of the engine valve stem and the valve lifter or rocker arm to compensate for expansion due to heat.

VAPOR LOCK—A condition wherein the fuel boils in the engine fuel system, forming bubbles which retard or stop the flow of fuel to the carburetor.

VENT—An air breathing device in a fluid reservoir.

VISCOSITY—The measure of resistance of a fluid to flow. An engine oil rating.

VOLATILITY—The tendency for a fluid to evaporate rapidly or pass off in the form of vapor. For example, gasoline is more volatile than kerosene as it evaporates at a lower temperature.

VOLTAGE—That force which is generated to cause current to flow in an electrical circuit. It is also referred to as electromotive force or electrical potential. Voltage is measured in volts.

VOLTMETER—An instrument for measuring the force in volts of an electrical current. This is the difference of potential (voltage) between different points in an electrical circuit. Voltmeters are connected across (parallel to) the points where voltage is to be measured.

VOLUME—The amount of fluid flow per unit time. Usually given as gallons per minute (gpm), or liters per minute (L/min).

W

WATT—Work done at the rate of the joule per second, or the rate of work represented by an electric current of one ampere under a pressure of one volt (symbol: W).

WIRING HARNESS—The trunk and branches which feed an electrical circuit. Wires from one part of the circuit enter the trunk, joining other wires, and then emerge at another point in the circuit.

ABBREVIATIONS

API—American Petroleum Institute (develops designations for various petroleum products)

ASAE—American Society of Agricultural Engineers (sets standards for many components for agricultural use)

BDC—bottom dead center (of an engine piston)

BTU—Abbreviation for *British Thermal Unit*. Amount of heat required to raise temperature of one pound of

(continued)

ABBREVIATIONS (cont.)

water (approximately one pint) 1° F. All substances are rated in relation to water as standard of measurement.

°C—degrees Celsius (of temperature) (formerly called centigrade)

cm—centimeter (length)

cm²—square centimeters (area)

cu. in.—cubic inch

°F—degrees Fahrenheit (of temperature)

ft.—feet

ft.-lbs—foot-pounds (of torque or turning effort)

gpm—gallons per minute (of fluid flow)

ha—hectare (area)

hp—horsepower

I.D.—inside diameter (as of a hose or tube)

in.—inch

J—joule (work or energy)

kg—kilogram (mass or weight)

km—kilometer (distance)

kPa—kilopascal (pressure)

kW—kilowatt (work or power)

L—liter (volume)

m—meter (length)

mph—miles per hour

N—Newton (force)

N·m—Newton-meter (torque)

mph—miles per hour

O.D.—outside diameter (as of a hose or tube)

psi—pounds per square inch (of pressure)

rpm—revolutions per minute

SAE—Society of Automotive Engineers (sets standards for many components for both automotive and agricultural use)

sq. ft.—square feet

sq. in.—square inch

TDC—top dead center (of an engine piston)

W—watt (work or power)

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Preventive Maintenance student workbook (FMO-16603W) contains corresponding chapter units based on FMO Preventive Maintenance text, with chapter quizzes, study and discussion activities, and laboratory exercises.

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